This report was funded by the Bonneville Power Administration (BPA), U.S. Department of Energy, as part of BPA's program to protect, mitigate, and enhance fish and wildlife affected by the development and operation of hydroelectric facilities on the Columbia River and its tributaries. The views in this report are the author's and do not necessarily represent the views of BPA.

For additional copies of this report, write to

Bonneville Power Administration
Public Information Center - CKPS-1
P.O. Box 3621
Portland, OR 97208

Please include title, author, and DOE/BP number from the back cover in the request

SURVIVAL ESTIMATES FOR THE PASSAGE OF THE YEARLING CHINOOK SALMON AND STEELHEAD THROUGH SNAKE RIVER DAMS AND RESERVOIRS, 1995

ANNUAL REPORT

Prepared by:

William D. Muir, Steven G. Smith, Eric E. Hockersmith, Stephen Achord
Randall F. Absolon, Paul A. Ocker, Brad M. Eppard, Thomas E. Ruehle
John G. Williams, Robert N. Iwamoto

Coastal Zone and Estuarine Studies Division
Northwest Fisheries Science Center
National Marine Fisheries Service
National Oceanic and Atmospheric Administration
Seattle, WA

and

John R. Skalski
School of Fisheries
Center for Quantitative Science
University of Washington
Seattle, WA

Prepared for:

U.S. Army Corps of Engineers
Walla Walla District
Contract E86940119

a n d

Department of Energy
Bonneville Power Administration
Environment, Fish and Wildlife
P.O. Box 3621
Portland, OR 97208-3621

Project Number 93-29
Contract Number DE-AI79-93BP10891

March 1996

EXECUTIVE SUMMARY

In 1995, the National Marine Fisheries Service and the University of Washington completed the third year of a multi-year study to estimate survival of juvenile salmonids passing through dams and reservoirs on the Snake River. Actively migrating yearling chinook salmon (*Oncorhynchus tshawytscha)* and steelhead (0. *mykiss*) smolts were collected at selected locations above, at, and below Lower Granite Dam, tagged with passive integrated transponder (PIT) tags, and released to continue their downstream migration. Individual smolts were subsequently detected at PIT-tag detection facilities at Lower Granite, Little Goose, Lower Monumental, McNary, John Day, and Bonneville Dams. Survival estimates were calculated using the Single-Release and Paired-Release Models.

Specific research objectives in 1995 were 1) to continue field testing and evaluating the Single-Release, Modified Single-Release, and Paired-Release Models for estimating survival probabilities of migrating juvenile salmonids, 2) to identify operational and logistical constraints that would limit the ability to collect data for the models, and 3) to collect baseline information on smolt travel time and survival under extant river conditions and dam operations. Timing of releases of tagged hatchery yearling chinook salmon (0. *tshawytscha*) and hatchery steelhead *(O. mykiss*) in 1995 spanned the major portion of their juvenile migrations.

Primary releases consisted of 12 groups of hatchery yearling chinook salmon (119 to 1,258 per group) and 11 groups of hatchery steelhead (148 to 1,249 per group). The majority of smolts were collected by purse seine near the Port of Wilma (about 49 km upstream from Lower Granite Dam), PIT tagged, and released at the same location. The remainder were purse seined

about 10 km downstream near Silcott Island and transported back upstream for PIT tagging and release.

Secondary releases consisted of replicate groups of hatchery yearling chinook salmon and steelhead released in the collection channels of juvenile bypass facilities and tailraces at Lower Granite, Little Goose, and Lower Monumental Dams. These releases were made to measure post-detection bypass survival (test of a model assumption). Release of these groups was timed to coincide with the approximate time of passage of the primary release groups at each dam. Fish for secondary releases were collected in the juvenile collection and bypass facilities at the dam at which they were released. Additional releases of hatchery yearling chinook salmon were made at Lower Granite Dam to estimate turbine survival.

During the spring outmigration, slide gates triggered by PIT-tag detectors at Lower Granite, Little Goose, Lower Monumental, and McNary Dams automatically returned most PIT-tagged smolts back to'the river. For fish from the primary and secondary release groups and from other PIT-tagged salmonids released from hatcheries, dams, and trap sites upstream from Lower Granite Dam, slide-gates allowed detections at multiple downstream dams.

PIT-tag detection rates varied widely in 1995, due at least in part to the effects of spill, particularly late in the season when spill levels increased. The increased spill resulted in lower detection rates and decreased precision in survival estimates.

Tests of assumptions of the Single-Release and Paired-Release Models showed more significant violations in 1995 than in 1993 and 1994. This result was probably due to large spill volumes that occurred at many dams throughout most of the migration season. The most common violation was a lack of downstream mixing between fish detected and those not detected at a dam. Detected fish, which passed via the juvenile bypass systems, often arrived more than a day later at the next downstream dam than nondetected fish, most of which probably passed via the spillway.

Lack of mixing between detected and nondetected fish might cause problems with model fit. However, tests designed to assess lack of fit did not show sufficient numbers of violations to invalidate model-based estimates. In general, results indicated that 1) detection at an upstream site did not influence the probability of its subsequent detection downstream, 2) detection did not influence subsequent survival, and 3) treatment and reference fish were mixed at subsequent detection sites. Moreover, post-detection bypass releases indicated that fish in the juvenile bypass system incurred negligible mortality between the point of detection and the zone of remixing with fish using other passage routes. Accordingly, the Single-Release Model was used to estimate survival probabilities for the primary release groups.

Accurate and precise survival estimates for a large portion of the 1995 hatchery yearling chinook salmon and hatchery steelhead migrations were obtained. Results indicated that survival from the primary release site (49 km upstream from Lower Granite Dam) to the tailrace of Lower Granite Dam averaged about 93% for hatchery yearling chinook salmon and 92% for hatchery steelhead. Survival from the tailrace of Lower Granite Dam to the tailrace of Little Goose Dam was about 90% for hatchery yearling chinook salmon and 91% for hatchery steelhead. From Little Goose Dam tailrace to Lower Monumental Dam tailrace, survival was 94% and 95% for hatchery yearling chinook salmon and hatchery steelhead, respectively.

The river sections over which survival was estimated for the primary release groups represent about 69% of the distance from the head of Lower Granite Reservoir to the confluence of the Snake and Columbia Rivers. The estimated survival probability from the Port of Wilma to Lower Monumental Dam tailrace (155 km) was 78% for hatchery chinook salmon and 80% for hatchery steelhead. These estimates are relatively high compared to those in the Snake River in earlier years (Raymond 1979), and slightly higher than our estimates in 1993 and 1994.

Mortality from the head of Lower Granite Reservoir to the tailrace of Lower Granite Dam was less than 10% for hatchery yearling chinook salmon and hatchery steelhead. Because this estimate included mortality associated with dam passage via turbines, bypass, and spill, it appeared that relatively little mortality occurred in the reservoir.

Survival estimates from Lower Granite Dam tailrace to Little Goose Dam tailrace for primary releases and hatchery releases were again the lowest observed among the three river sections investigated in 1995. However, they were higher than estimates for this section in 1994.

Survival estimates in each of the reaches investigated during 1995 were higher for both hatchery yearling chinook salmon and hatchery steelhead than in previous years. We attribute this increase in part to improved migration conditions due to higher flows and a higher proportion of smolts passing via non-turbine routes due to the spill program, which begain earlier in 1995.

Survival was estimated for PIT-tagged yearling chinook salmon released in the tailrace of Lower Granite Dam throughout the migration season. These fish were part of an experiment to compare the adult return rates of chinook salmon that were transported by barge from Lower Granite Dam to a point below Bonneville Dam and those that migrated through the Snake and Columbia River hydropower system. Because of the large number of fish released in this evaluation, we were able to estimate survival of both wild and hatchery yearling chinook salmon through an additional river section with the Single Release Model: from Lower Monumental Dam tailrace to McNary Dam tailrace. No post-detection evaluations were made at McNary Dam.

A total of 136,079 PIT-tagged yearling chinook salmon were released in the tailrace at Lower Granite Dam to compare against transported fish. With this large number of tagged fish, there were sufficient detections at John Day and Bonneville Dams to estimate survival to McNary Dam tailrace for most of the migration season (9 April through 13 May). Survival estimates for wild yearling chinook salmon from this evaluation were similar to estimates for hatchery fish. Survival from Lower Monumental tailrace to McNary Dam tailrace (two dams and two reservoirs) was 85% for hatchery yearling chinook salmon and 83% for wild yearling chinook salmon. From Lower Granite Dam tailrace to McNary Dam tailrace, survival was 71% and 70% for hatchery and wild yearling chinook salmon, respectively.

Based on the results of 3 years of research (1993-1995), we conclude that the Single-Release, Modified Single-Release, and Paired-Release Models can be used to make accurate precise estimates of juvenile salmonid passage survival through individual river sections, reservoirs, and hydroelectric projects in the Snake and Columbia Rivers.

CONTENTS

LIST OF FIGURES

PAGE

LIST OF TABLES

INTRODUCTION

Survival estimates for juvenile chinook salmon (*Oncorhynchus tshawytscha*) and steelhead (0. *mykiss*) that migrate through reservoirs, hydroelectric projects, and free-flowing sections of the Snake and Columbia Rivers are essential to develop effective strategies to recover depressed stocks. Many management strategies, however, rely upon outdated estimates of system survival (Raymond 1979, Sims and Ossiander 198 1) that lacked statistical precision and that were derived in a river system considerably different from today's (Williams and Matthews 1995). Knowledge of the magnitude, locations, and causes of smolt mortality under present passage conditions and under conditions projected for the future are necessary to develop strategies that will optimize smolt survival.

In 1993 and 1994, the National Marine Fisheries Service (NMFS) and the University of Washington (UW) demonstrated the feasibility of using three statistical models to estimate survival of PIT-tagged (Prentice et al. 1990a) juvenile salmonids passing through Snake River dams and reservoirs (Iwamoto et al. 1994, Muir et al. 1995). Evaluation of assumptions for these models indicated that all were generally satisfied, so that accurate and precise survival estimates were obtained for a portion of the 1993 and most of the 1994 migration of hatchery yearling chinook salmon, and for most of the 1994 migration of hatchery steelhead.

In 1995, NMFS and UW completed the third year of the multi-year study. Specific research objectives were to 1) continue field tests and evaluation of the Single-Release, Modiied Single-Release, and Paired-Release Models for estimating survival probabilities through river sections and hydroelectric projects; 2) identify operational and logistical constraints that would limit the ability to collect data required for the models; and 3) provide baseline survival and travel time data for hatchery yearling chinook salmon and juvenile hatchery steelhead.

METHODS

Experimental Design

Three statistical models were used to estimate survival from PIT-tag data in 1995 : the Single-Release (SR) (Cormack 1964, Jolly 1965, Seber 1965), Modiied Single-Release (MSR) (Hoffmann and Skalski, statistical appendix in Dauble et al. 1993), and Paired-Release (PR) Models (Burnham et al. 1987). Background information and statistical theory underlying these models were presented by Iwamoto et al. (1994).

During the 1995 migration season, automatic PIT-tag detectors (Prentice et al. 1990a; 1990b; 1990c) were operational in the juvenile bypass systems at Lower Granite (RKm 695), Little Goose (RKm 635), Lower Monumental (RKm 589), and McNary Dams (RKm 470) (Figs. 1 and 2). Further, the majority of PIT-tagged fish detected were diverted back to the river by slide gates (rather than being barged or trucked downstream), which allowed for the possibility of detection of an individual fish at more than one downstream site. Although no automatic detectors existed at John Day and Bonneville Dams, fish sampled from gatewells at John Day Dam and from the bypass system at Bonneville Dam were interrogated for PIT tags.

Two series of primary releases were made using PIT-tagged hatchery yearling chinook salmon and hatchery steelhead juveniles captured by purseseine near the head of Lower Granite Reservoir (RKm 744). We used the records of downstream PIT-tag detections to estimate survival from the point of release to Lower Granite Dam tailrace, from Lower Granite Dam tailrace to Little Goose Dam tailrace, and from Little Goose Dam tailrace to Lower Monumental Dam tailrace. In some cases, we had sufficient detections at John Day and Bonneville Dams to

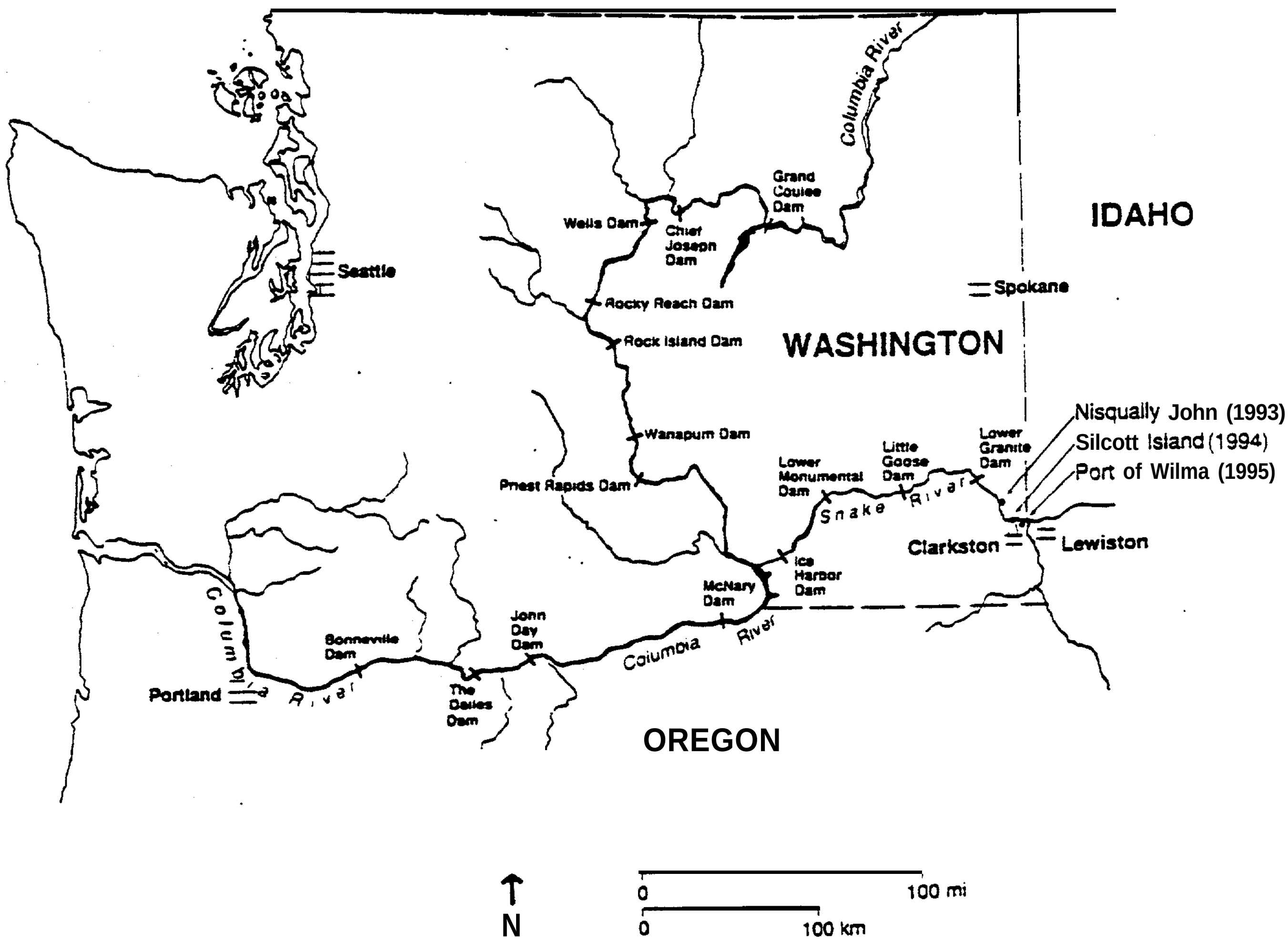


Figure 1. Study area showing release and detection sites.

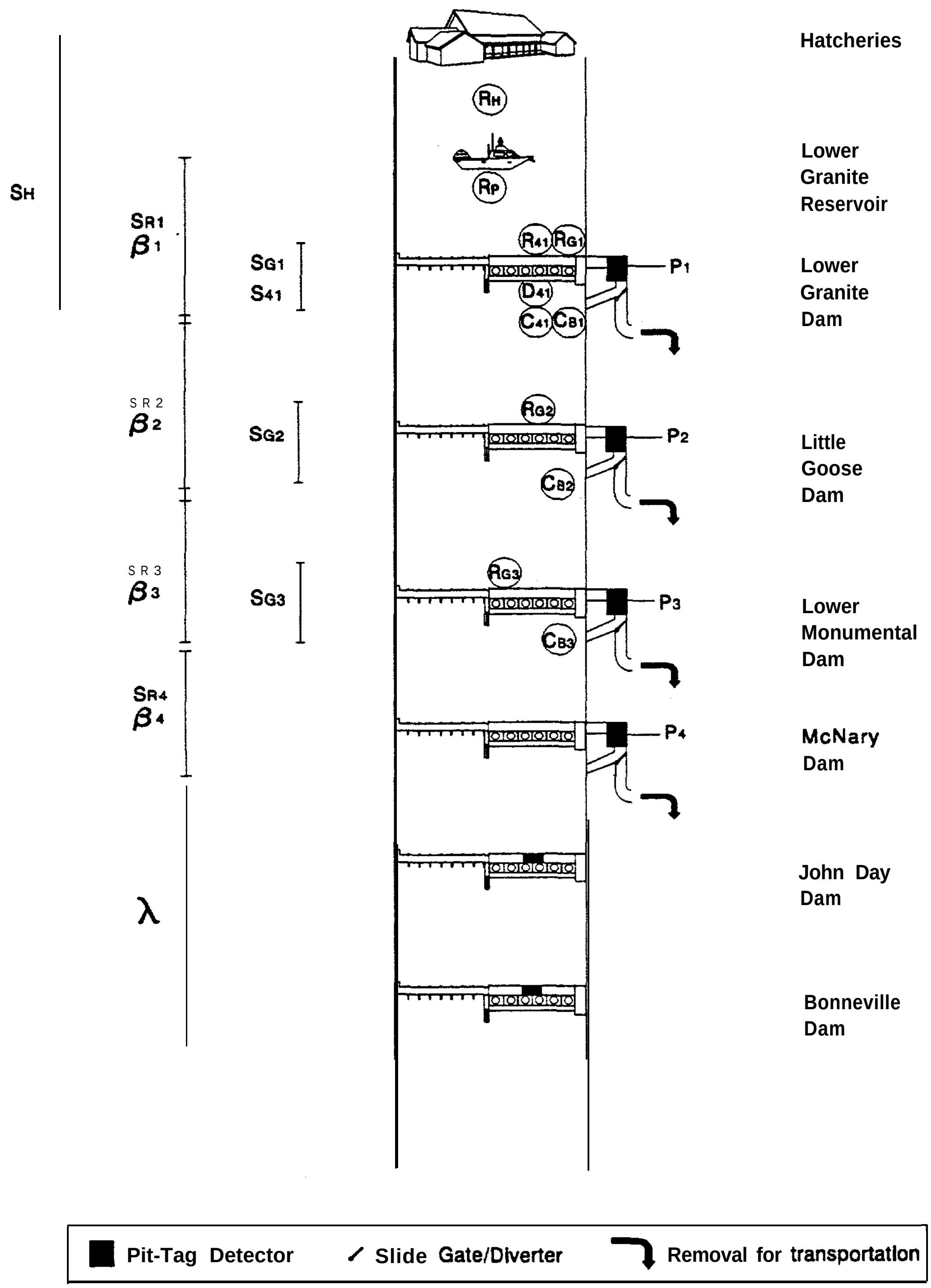


Figure 2. Schematic of study area showing location of study sites, release groups (circled), and estimated parameters. (See Tables 1 and 2 for release group and parameter definitions).

estimate survival in the river section from Lower Monumental Dam tailrace to McNary Dam tailrace. Sufficient numbers of hatchery and wild yearling chinook salmon were released in the tailrace of Lower Granite Dam (as part of a large-scale transportation study) to estimate survival to McNary Dam tailrace for the peak of the migration.

Paired secondary releases were conducted at Lower Granite, Little Goose, and Lower Monumental Dams to estimate post-detection bypass mortality. Data from each set of paired releases were analyzed using the PR Model to determine if mortality occurring in the bypass system after fish were detected was significant enough at each dam to require the use of the MSR Model to analyze the releases above Lower Granite Dam.

Additional paired releases were conducted at Lower Granite Dam to evaluate passage survival through turbines. Data from these releases were also analyzed using the PR Model.

In addition to the primary releases, survival probabilities were also estimated from PIT-tagged smolts released from hatcheries and fish traps in the Snake River Basin and into the tailrace at Lower Granite Dam for transportation evaluation.

Primary Release Groups

The primary release groups (R_p) consisted of hatchery yearling chinook salmon and hatchery steelhead captured in Lower Granite Reservoir (Table 1). Fish were collected using two purse-seine vessels fished simultaneously. Seining was conducted near the Port of Wilma and, on several occasions, just upstream from Silcott Island. Fish were PIT tagged on an 1 l-m marking barge moored at the Port of Wilma Dock (see Muir et al. 1995 for details on fish collection, handling, and tagging). There were 12 releases of hatchery yearling chinook salmon and 11

Table 1. Release groups of PIT-tagged yearling chinook salmon and steelhead for 1995 survival studies.

Release	Definition
R_P	Primary release groups of hatchery fish, Lower Granite Reservoir
R_{B1}	Post-detection bypass treatment release groups, Lower Granite Dam
C_{B1}	Bypass reference release groups, Lower Granite Dam
R_{41}	Turbine Unit 4 treatment release groups, Lower Granite Dam
C_{41}	Turbine Unit 4 bypass system reference release groups, Lower Granite Dam
D_{41}	Turbine Unit 4 draft tube reference release groups, Lower Granite Dam
R_{B2}	Post-detection bypass treatment release groups, Little Goose Dam
C_{B2}	Bypass reference release groups, Little Goose Dam
R_{B3}	Post-detection bypass treatment release groups, Lower Monumental Dam
C_{B3}	Bypass reference release groups, Lower Monumental Dam
R_H	Hatchery release groups

releases of hatchery steelhead over the course of the spring migration. Recapture histories from each group were used in the SR Model to estimate survival for three river sections: from release to Lower Granite Dam tailrace (S,,), from Lower Granite Dam tailrace to Little Goose Dam tailrace (S_{R2}), and from Little Goose Dam tailrace to Lower Monumental Dam tailrace (S,) (Tables 2 and 3, Fig. 2).

Most yearling chinook salmon and steelhead PIT tagged and released in the reservoir for the primary release groups were kept in net-pens (1.8 × 0.9 × 0.7 m) (Rottiers 1991) for approximately 24 hours prior to release. However, when insufficient numbers of fish were captured to complete a release group on a single day, additional fish were captured and tagged the following day. Fish captured on the second day to complete a release group were held less than 24 hours prior to release. The net-pens were secured beneath the Port of Wilma Dock in a protected, shaded area, out of the main current. For release, they were towed offshore and into the main current several hundred meters downstream from the dock. Mortalities were removed, and the net-pens were rolled over to permit fish to escape. All releases were made between 1100 and 1400 hours.

Gill tissue was sampled from anesthetized fish from most release groups of hatchery yearling chinook salmon (30 fish per group) for Na^{+}-K^{+} ATPase assays, which were performed by the National Biological Service (NBS). Sampled fish were returned to their release group.

Post-detection Bypass Paired Release Groups

Paired releases were made at Lower Granite (R_{B1}, C_{B1}), Little Goose (R_{B2}, C_{B2}), and Lower Monumental Dams (R_{B3}, C_{B3}) (Table 1). The post-detection bypass treatment groups were

Table 2. Definition of parameters estimated from releases.

Parameter	Definition
S_{R1}	Probability of survival from point of primary release to tailrace of Lower Granite Dam (Lower Granite Dam "reach" survival).
S_{B1}	Probability of survival from just below slide gate to bypass outfall at Lower Granite Dam (Lower Granite Dam post-detection bypass survival).
S_{41}	Probability of survival from release into Turbine Unit 4 to tailrace of Lower Granite Dam (Lower Granite Dam Turbine Unit 4 survival).
P_1	Probability of detection at Lower Granite Dam, given that fish survived to Lower Granite Dam.
β_1	Vector of slope parameters for covariates affecting survival from primary release point to Lower Granite Dam tailrace.
S_{R2}	Probability of survival from Lower Granite Dam tailrace to Little Goose Dam tailrace (Little Goose Dam "reach" survival).
S_{B2}	Probability of survival from just below slide gate to bypass outfall at Little Goose Dam (Little Goose Dam post-detection bypass survival).
P_2	Probability of detection at Little Goose Dam, given that fish survived to Little Goose Dam.
β_2	Vector of slope parameters for covariates affecting survival from Lower Granite Dam tailrace to Little Goose Dam tailrace.
S_{R3}	Probability of survival from Little Goose Dam tailrace to Lower Monumental Dam tailrace (Lower Monumental Dam "reach" survival).
S_{B3}	Probability of survival from just below slide gate to bypass outfall at Lower Monumental Dam (Lower Monumental Dam post-detection bypass survival).
P_3	Probability of detection at Lower Monumental Dam, given that fish survived to Lower Monumental Dam.
β_3	Vector of slope parameters for covariates affecting survival from Little Goose Dam tailrace to Lower Monumental Dam tailrace.
λ	Probability that a fish surviving to Lower Monumental Dam tailrace is eventually detected at McNary Dam (includes McNary Dam "reach" survival and probability of detection at McNary Dam).
S_H	Probability of survival from release at hatchery to tailrace of Lower Granite Dam.

Table 3. Parameters estimated from each set of releases.

Set of releases	Parameters estimated	Model for analysis
R_P, R_{B1}, C_{B1}	S_{R1}, S_{B1}, P_1 β_1	Single-release (Modified if necessary)
R_{41}, C_{41}	S_{41}	Paired-release (Complete capture history)
R_{41}, D_{41}	S_{41}	Paired-release (Complete capture history)
R_P, R_{B2}, C_{B2}	S_{R2}, S_{B2}, P_2 β_2	Single-release (Modified if necessary)
R_P, R_{B3}, C_{B3}	S_{R3}, S_{B3}, P_3 β_3	Single-release (Modified if necessary)
R_H, R_{B1}, C_{B1}	S_H	Single-release (Modified if necessary)

released into the collection channel above the juvenile collection facility at each dam. Fish successfully diverted back to the river by the slide-gate system became the post-detection bypass treatment group (R_{B1}, R_{B2}, R_{B3}). Reference groups (C_{B1}, C_{B2}, C,,) were released into the river below the dam in the zone where detected fish remixed with nondetected fish.

Preliminary analyses of recapture histories from these paired tailrace releases were conducted using the PR Model to determine whether significant mortality occurred between the time of detection and the time of remixing with nondetected fish. If post-detection mortality was not significant, primary releases were analyzed using the SR Model; otherwise, the MSR Model was applied. The post-detection bypass releases at each dam were the secondary releases for the MSR Model.

Analysis of bypass-system releases did not provide an estimate of overall mortality associated with the entire route through the juvenile bypass system: fish were not exposed to the submersible traveling screens, gatewells, or orifice passage into the collection channel. The purpose of these releases was solely to estimate post-detection bypass mortality.

Only hatchery yearling chinook salmon and hatchery steelhead, determined by the absence of either adipose or ventral fins, were used for releases at the dams. At each dam, there were five replications of each set of releases using hatchery steelhead. For hatchery yearling chinook salmon, there were four replications of paired releases at Lower Granite Dam and five replications at Lower Monumental Dam. No releases of hatchery yearling chinook salmon were made at Little Goose Dam.

Fish for releases at dams were obtained from the juvenile collection facility at each respective dam. Collection, marking, and release procedures were generally the same as those used in 1994 (Muir et al. 1995). The collection-channel release hose (7.6 cm × 12.2 m) used at Lower Granite Dam extended from the intake deck through an opening in Gatewell 6A into the collection channel with its terminus just below the water surface (Fig. 3). At Little Goose Dam, the collection-channel release hose (7.6 cm × 12.4 m) extended through an opening in Gatewell 6C into the collection channel (Fig. 4). At Lower Monumental Dam, the release hose (7.6 cm x 23.8 m) extended through an opening in gatewell 6C (Fig. 5).

Turbine Paired Release Groups

Two replicated sets of releases were made at Lower Granite Dam (R_{41}, C_{41}, D_{41}) to estimate turbine mortality for hatchery yearling chinook salmon (Table 1). Treatment groups (R_{41}) were released through hoses directly into the turbine intake using the apparatus installed by RMC Environmental Services for turbine survival research using balloon tags (Normandeau Associates, Inc. and Skalski 1995). Draft tube reference groups (D_{41}) were released into the draft tube on the downstream side of the dam, using the apparatus installed for the RMC balloon-tag study. Bypass system reference groups (C_{41}) were released into the outfall pipe of the juvenile bypass facility.

The turbine treatment, draft tube reference, and downstream reference release groups were held overnight in 120-L plastic containers with flow-through water. To maintain an equal density of about 100 fish per container required 16 containers for the treatment group and 8 containers for each of the reference groups.

The turbine-release hose (10.2 cm × 53.3 m) was attached to the submersible traveling screen (STS) in Slot 4B (Fig. 3). Its terminus was at elevation 183.8 m above sea level. The

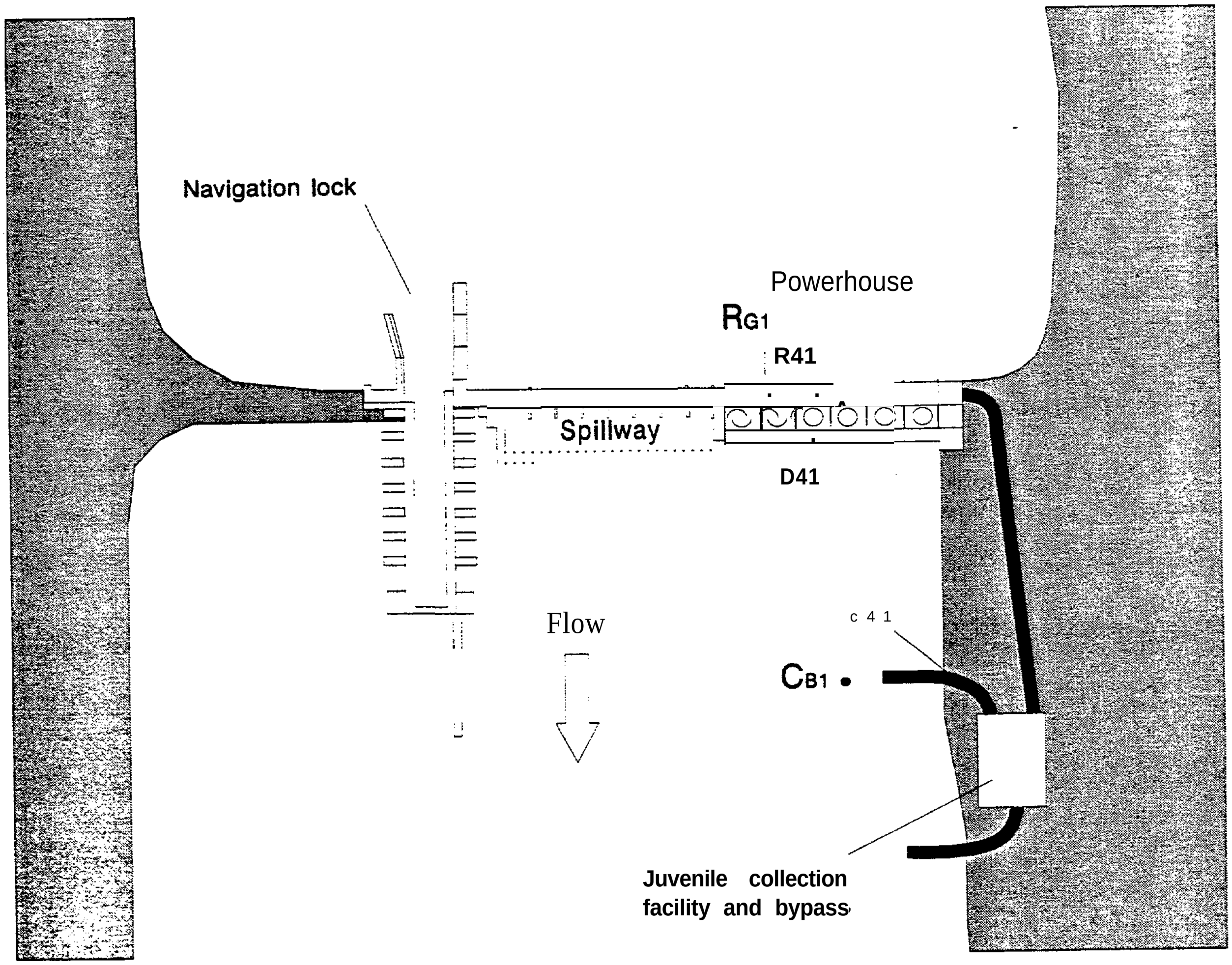


Figure 3. Schematic of Lower Granite Dam showing locations of collection channel (R_{G1}), draft tube (D_{41}), turbine (R_{41}), and reference (C_{B1}, C_{41}) releases.

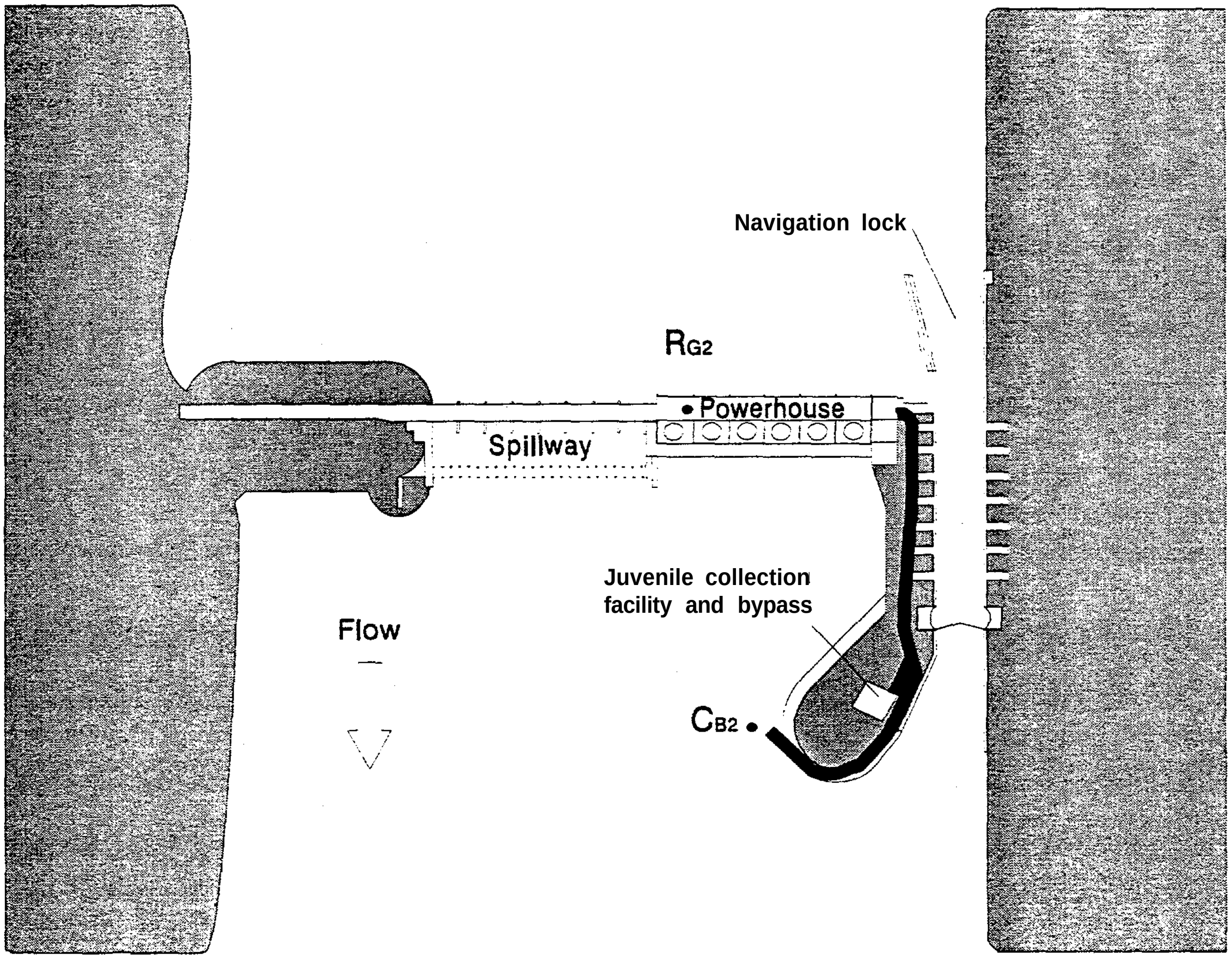


Figure 4. Schematic of Little Goose Dam showing locations of collection channel (R_{G2}) and reference (C_{B2}) releases.

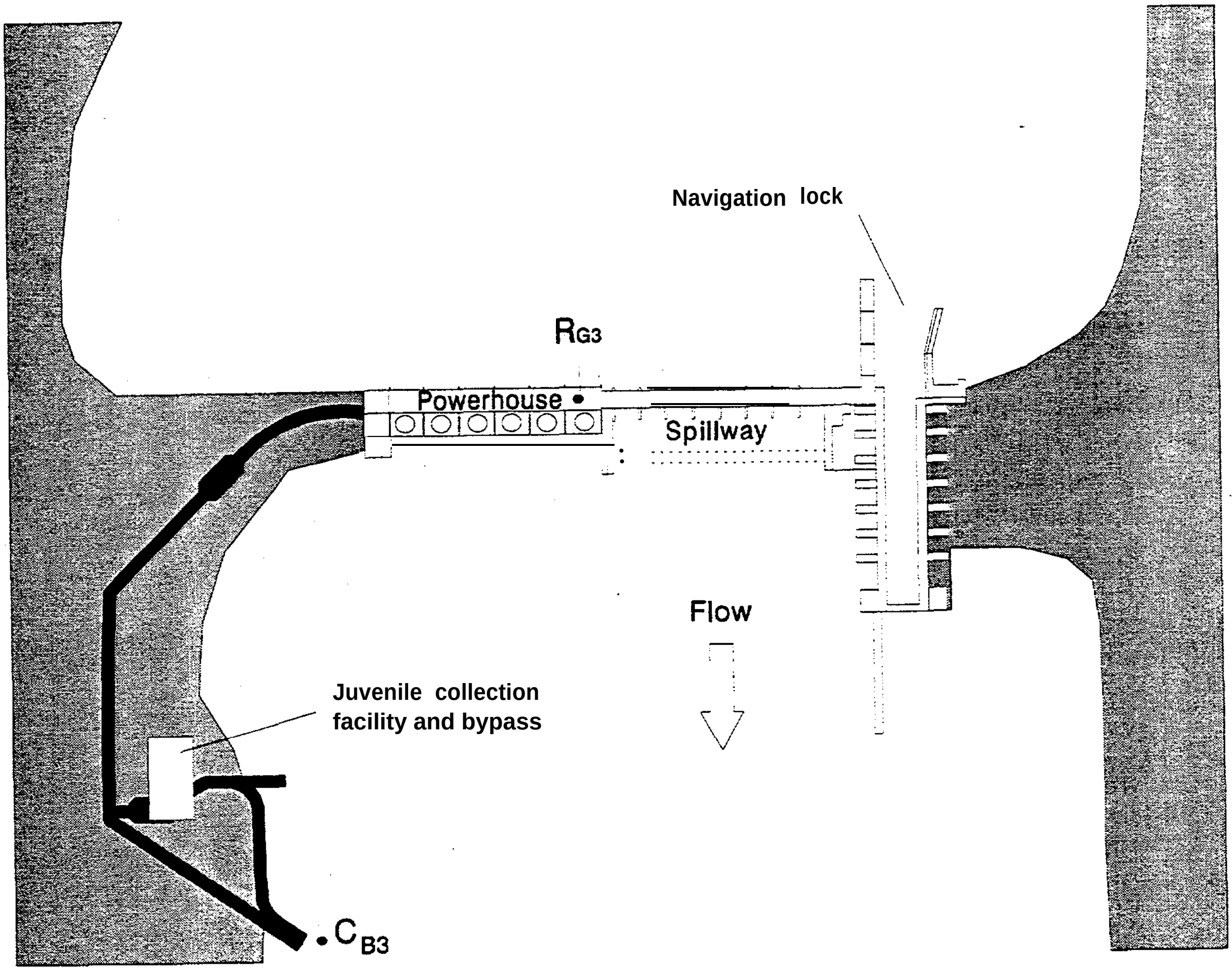


Figure 5. Schematic of Lower Monumental Dam showing locations of collection channel (R_{G3}) and reference (C,,) releases.

draft-tube release hose was 10.2-cm by 30.5-m and terminated 173.7 m above sea level. Emergency deck water was used to flush the hoses continually during and after all releases. Fish were released throughout the day at each release location. At hourly intervals, two containers were emptied at the treatment release site and one container was emptied at each of the two reference release sites.

The two reference groups were analyzed using the PR Model. If the two groups mixed evenly during downstream passage and were found to have equal survival and capture parameters, they were pooled as a single reference group for the turbine release group. If the two reference releases differed in downstream passage distribution or parameters, the group that had passage distributions most siilar to the treatment group was used as the reference group. Estimates of turbine-passage survival were obtained using the PR Model for the treatment group and the appropriate reference group.

Lower Granite Tailrace Release Groups

Both hatchery and wild yearling chinook salmon were PIT tagged and released daily in the tailrace of Lower Granite Dam as part of a study to compare the rates of adult returns for fish migrating in the river versus those transported (trucked or barged) downstream for release below Bonneville Dam. The goal was to PIT tag a constant proportion of migrants arriving at Lower Granite Dam throughout the migration season. To estimate survival probabilities for juvenile migration using these releases, daily tailrace releases were pooled into weekly release groups. Survival was estimated for the river section from Lower Granite Dam tailrace to Little Goose Dam tailrace, and from Little Goose Dam tailrace to Lower Monumental Dam tailrace using the

SR Model. Some of the pooled release groups had sufficient detections at John Day and Bonneville Dams to allow estimation of survival from the tailrace of Lower Monumental Dam to the tailrace of McNary Dam.

Methods for collecting, tagging, and releasing yearling chinook salmon for the transportation evaluation were similar to those used for our secondary paired releases (Marsh et al. in prep).

Project Operations

Slide-Gate Operation

To divert PIT-tagged fish back to the river, slide-gate systems were operated at Lower Granite, Little Goose, Lower Monumental, and McNary Dams (Achord et al. 1992) for the duration of the study. At Lower Granite Darn, operations began on 29 March; at Little Goose and Lower Monumental Dams, on 2 April; and at McNary Dam, on 28 March. Slide-gate or diversion efficiency (through the end of June) at each dam was determined by comparing the number of PIT-tagged smolts detected in the bypass system upstream from the slide gate with the number detected downstream in the same bypass system.

Turbine Load and Spill

Turbine load, spill-gate settings, forebay elevation, and tailrace elevation at the time of each release of PIT-tagged fish at Lower Granite, Little Goose, and Lower Monumental Dams were obtained from operators' logs at each project. Daily average flow and spill for each dam equipped with a PIT-tag detection system were obtained from Fish Passage Center weekly reports.[1]

Data Analysis

Tagging and detection data were retrieved from the PIT Tag Information System (PTAGIS) maintained by the Pacific States Marine Fisheries Commission.[2] Data were examined for erroneous records, inconsistencies, and data anomalies. Records were eliminated where appropriate, and all eliminated PIT-tag codes were recorded with the reasons for their elimination. For each remaining PIT-tag code, a record ("capture history") was constructed to indicate at which dams the tagged fish was detected and at which it was not detected. Methods for data retrieval, database quality assurance/control, and construction of capture histories were the same as those used in 1994 (Muir et al. 1995).

Tests of Assumptions

A primary objective of the studies in 1995 was to test the statistical validity of the SR, MSR, and PR Models as applied to the data generated from PIT-tagged juvenile salmonids in the Snake River. Validity of the models was tested by evaluating critical assumptions. Details of the methods used to test assumptions are in Appendix A

---

[1]Fish Passage Center, Suite 230, 2501 S. W. First Ave., Portland, OR 97201-4752.

[2]Pacific States Marine Fisheries Commission, PIT Tag Operations Center, 45 SE 82nd Drive, Suite 100, Gladstone, OR 97207.

Survival Estimation

Because there were multiple detection sites downstream from Little Goose Dam, the "complete capture history" protocol (Burnham et al. 1987) was used to analyze paired releases from Lower Granite and Little Goose Dams. For paired releases from Lower Monumental Dam, detections at John Day and Bonneville Dams were insufficient to support the complete capture history protocol, therefore the "first capture history" protocol (Burnham et al. 1987) was used.

Under the complete capture history protocol, the probability of survival for the passage route was estimated by applying the SR Model independently to test and reference groups. For reference groups, survival probability from the point of release to the next downstream dam was defined as S,, and for test groups it was defined as the product of S_R and the probability of surviving turbine passage (e.g. S_{41} for Lower Granite Dam turbiie releases) or surviving between the point of detection and the remixing zone (e.g. S_{B2} for Little Goose Dam post-detection bypass releases). The survival probability for the passage route was estimated as the ratio of the estimated survival probability for the test group to that for the reference group. Under the first capture history protocol, the probability of survival for the passage route was estimated as the ratio of the proportion of the treatment group detected at McNary, John Day, or Bonneville Dam to the proportion of the reference group detected ("relative recovery").

The 1995 spring juvenile migration season was the first during which a slide gate was operating at McNary Dam to return detected PIT-tagged fish to the river. In addition, gatewells at John Day Dam and the bypass system at Bonnneville Dam were sampled for PIT-tagged fish in 1995. Thus, for the first time, it was possible to estimate survival from Lower Monumental Dam tailrace to McNary Dam tailrace. For groups with sufficient detections at John Day and

Bonneville Dams, the capture histories for individual fish were extended by a single digit to indicate detection at John Day and/or Bonneville Dam. However, because no paired releases were made in the bypass system at McNary Dam, post-detection survival was assumed to be 100% at McNary Dam.

Estimates of survival probabilities under the SR, MSR and PR Models are random variables, subject to sampling variability. When true survival probabilities are close to 1 .O and/or when sampling variability is high, it is possible for estimates of survival probabilities to exceed 1.0. For practical purposes estimates should be considered equal to 1 .O in these cases.

When estimates for a particular river section or passage route were available from more than one release or pairs of releases, the estimates were often combined using a weighted average. Weights were inversely proportional to the respective estimated variances, thus providing a weighted average with minimum standard error (Hunter et al. 1982). The formula for the weighted average was:

$$S_w = \frac{\sum_{i=1}^{I} w_i \hat{S}_i}{\sum_{i=1}^{I} w_i} \qquad (1)$$

where $\hat{S}_i$ is the ith of a total of I survival estimates and w_i is the respective weight. The variance of the weighted average was estimated using the formula:

$$\hat{Var}(S_w) = \frac{\sum_{i=1}^{I} w_i (\hat{S}_i - S_w)^2}{(I - 1)\sum_{i=1}^{I} w_i} \qquad (2)$$

A statistical computer program for analyzing release-recapture data was used to perform all survival analyses. This program was developed at the University of Washington and named SURPH, for “Survival with Proportional Hazards,” (Skalski et al. 1993, Smith et al. 1994). This program extends the standard Single-Release Models (Cormack 1964, Jolly 1965, Seber 1965) to allow simultaneous analysis of release-recapture data from multiple release groups. Parameters can be constrained to be equal across release groups, while other parameters remain unique to a group. In addition, parameters can be modeled as functions of covariates, on both the individual (e.g., length) and group level (e.g., release date).

Hatchery Releases

In 1995, several hatcheries released PIT-tagged fish for experiments designed at the hatcheries. Data from hatchery releases of PIT-tagged fish were analyzed to demonstrate survival estimation methods using the PIT-tag detection and slide-gate systems for automatic data collection. In addition, these analyses helped to evaluate the extent to which hatchery releases corroborated the results from our primary and secondary releases. In the course of characterizing the various hatchery releases, preliiary analyses were performed to determine whether data from multiple releases could be pooled to increase sample sizes. We neither intended nor attempted to analyze the experiments for which the hatchery releases were made.

Detections of PIT-tagged yearling chinook salmon and steelhead were analyzed from the following hatcheries (Table 4):

1) Dworshak National Fish Hatchery (United States Fish and Wildlife Service (USFWS)): Four treatment groups and a control group of approximately 800 PIT-tagged yearling chinook

Table 4. Releases of PIT-tagged yearling chinook salmon and steelhead from Snake River hatcheries during 1995 survival studies.

Hatchery	Release site	Date	Species	Number of releases	Number per release*	Total number released*
Dworshak	Dworshak NFH	14 Apr	Chinook	5	800	4,000
Dworshak	Clear C. and Clearwater R.	17 Apr	Steelhead	2	325	650
Dworshak	Dworshak NFH	24-28 Apr	Steel head	14	various	4,500
Kooskia	Kooskia H	12 Apr	Chinook	2	600	1,200
Kooskia	Clear C.	12 Apr	Chinook	1	500	500
Lookingglass	lmnaha Weir	28 Mar	Chinook	10	250	2,500
(Imnaha stock)	Imnaha Weir	5 Apr	Chinook	3	167	500
	Imnaha Weir	24-26 Apr	Chinook	4	250	1,000
Lookingglass (Rapid R. stock)	Lookingglass H	6 Apr	Chinook	8	250	2,000
Lookingglass (Irrigon stock)	Big Canyon	21 Apr	Chinook	1	114	114
McCall	Knox Bridge	6-7 Apr	Chinook	12	various	6,300
	Knox Bridge	19 Apr	Chinook	2	400	800
	Knox Bridge	24 Apr	Chinook	1	400	400

Table 4. Continued.

Hatchery	Release site	Date	Species	Number of releases	Number per release*	Total number released*
Rapid River	Rapid River H	31 Mar	Chinook	2	500	1,000
	Rapid River H	31 Mar	Chinook	2	500	1,000
	Hell's Canyon	30 Mar	Chinook	1	500	500
Pahsimeroi	Pahsimeroi Pond	12 Apr	Chinook	1	500	500
Sawtooth	Sawtooth H	5-7 Apr	Chinook	3	500	1,500
Sawtooth	Salmon R and East Fork Salmon R	27-28 Mar	Chinook	5	various	1,300

* Approximate numbers.

salmon each were released from Dworshak NFH on 14 April as part of an evaluation of a new antibiotic treatment. About 4,500 PIT-tagged steelhead were released from Dworshak NFH from 24 to 28 April, and releases of about 300 PIT-tagged steelhead each were made into the Clear-water River and Clear Creek on 17 April.

2) Kooskia National Fish Hatchery (USFWS): Releases of PIT-tagged yearling chinook salmon were made on 12 April. Two releases of 600 fish each were made at the hatchery, and one release of 500 fish was made into Clear Creek.

3) Lookingglass Hatchery (Oregon Department of Fish and Wildlife (ODFW)): Approximately 2,000 PIT-tagged yearling chinook salmon (Rapid River stock) were released from the hatchery on 6 April. Releases of PIT-tagged yearling chinook salmon (Imnaha stock) were made at the Imnaha Weir on 28 March, 5 April, and 24-26 April, with about 2,500, 500, and 1,000 tagged fish during each period, respectively. An additional 114 PIT-tagged yearling chinook salmon (Irrigon stock) were released at Big Canyon on 21 April.

4) McCall Hatchery (Idaho Department of Fish and Game (IDFG)): Releases of 400 to 800 PIT-tagged yearling chinook salmon were made on 7, 19, and 24 April as part of a time-of-release study, and 1 group of about 2,800 was released on 6 April for an adult evaluation. Two groups of approximately 1,000 fish each were released on 7 April; one group was PIT tagged by hand, while the other using an auto-injector. Two other groups of 500 and 600 PIT-tagged yearling chinook were also released on 7 April for supplementation studies and PIT-tag training.

5) Rapid River Hatchery (IDFG): Two groups of approximately 1,000 PIT-tagged yearling chinook salmon each were released on 3 1 March, with one group PIT tagged by hand

and the other PIT tagged using an auto-injector. An additional group of 500 was released in Hells Canyon on 30 March.

6) Sawtooth Hatchery (IDFG): Approximately 800 PIT-tagged yearling chinook salmon were released on 27 March in the Salmon River and about 500 on 28 March in the East Fork of the Salmon River. An additional group of 1,500 was released from the hatchery between 5 and 7 April.

7) Pahsimeroi Hatchery (IDFG): A single release from a hatchery pond of about 500 PIT-tagged yearling chinook salmon was made on 12 April.

For each hatchery, each set of releases was examined to determine suitability for survival analysis. The Single-Release Model was applied to each pooled data set to estimate the same probabilities as for our primary releases (Fig. 2, Tables 2 and 3). Survival estimates were not calculated for releases of PIT-tagged hatchery and wild chinook salmon parr because release and detection numbers were too small.

Fish Trap Releases

During the 1995 juvenile salmonid migration season, fish traps were operated by the Smolt Monitoring Program at sites on the Salmon (RKm 926), Snake @Km 747), and Clearwater (RKm 756) Rivers. Throughout the season, samples of daily catches of hatchery and wild chinook salmon and steelhead at the traps were PIT tagged and released. Fish of each species and rearing type released from each trap in the period during which we made our primary releases at the Port of Wilma were pooled into a single release group. Survival probabilities were estimated for the pooled groups.

Travel Time

Travel times were calculated for fish from primary releases through four river sections: 1) Port of Wilma to Lower Granite Dam, 2) Lower Granite Dam to Little Goose Darn 3) Little Goose Dam to Lower Monumental Dam, and 4) Lower Monumental Dam to McNary Dam. Travel time from Port of Wilma to Lower Granite Dam was calculated for each fish detected at Lower Granite Dam as the number of days between the time of release and the time of first detection at Lower Granite Dam. Travel time between any two dams was calculated for each fish detected at both dams as the number of days between last detection at the upstream dam and first detection at the downstream dam. Travel time included the time requried to move through the reservoir to the forebay of the downstream dam and any delay associated with residence in the forebay before entry into the bypass system.

To facilitate comparisons among the four river sections, rate of migration in each section (kilometers per day) was also calculated. Lengths of the river sections are 49 km from Port of Wilma to Lower Granite Dam, 60 km from Lower Granite Dam to Little Goose Dam, 43 km from Little Goose Dam to Lower Monumental Dam, and 119 km from Lower Monumental Dam to McNary Dam. Rate of migration through a river section was calculated as the length of the section (km) divided by the travel time (days) (which included any delay at dams as noted above). The minimum, 20th percentile, median 80th percentile, and maximum travel times and migration rates were determined from the distributions for each release group.

The complete set of travel times for a release group includes travel times of both detected and undetected fish. However, using PIT tags, travel times cannot be determined for fish that traverse a river section but are not detected at one or both ends of the section. Thus, travel time statistics were computed from travel times for detected fish only, representing a sample of the complete set.

During 1995, substantial spill volumes occurred at ail dams, resulting in lower detection rates. Some release groups had fish passiig Lower Granite Dam both before and after large spill volumes began at that site on 4 May. Spill volumes also increased at Lower Monumental and McNary Dams around the same date. For these groups, the faster migrants (early part of the passage distribution) were sampled more heavily than the slower migrants (late part of the distribution) because detection rates were higher under lighter spill. Thus, the distributions of observed travel times for these groups were biased toward shorter travel times, or faster migration rates. Travel time distributions were not biased for release groups that passed dams entirely before spill began or entirely after spill began.

RESULTS

Logistics and Feasibility

Lower Granite Reservoir

Purse seining in Lower Granite Reservoir near the Port of Wilma began on 8 April and continued until 12 May, with two to seven sets made each day by the two purse seiners (Table 5). On several dates, purse seining was conducted about 10 km downstream near Silcott Island, 'and fish transported back upstream for marking. Species composition varied by time of day, with the highest percentage of chinook salmon captured near dawn. Steelhead were the predominant species during daylight hours. The time of purse-seining effort was adjusted to target whichever species was needed for tagging each day. When fish in excess of those needed for tagging were captured, they were released without handling.

A total of 15,469 yearling chinook salmon were captured and handled in Lower Granite Reservoir, and 91.8% of these were fin clipped, indicating hatchery origin. Of the 16,921 juvenile steelhead captured and handled, 94.2% were of hatchery origin (Table 5). An additional 4 1 adult steelhead and 1 adult chinook salmon were also captured (Table 6). Handling mortality was low for all species in Lower Granite Reservoir, averaging less than 0.2% overall (Table 5).

The number of nonsahnonids (669) captured by purse seine in the reservoir was small (Table 6) compared to the number of salmonids (32,401).

A total of 11,05 1 hatchery yearling chinook salmon and 11,120 hatchery steelhead were tagged for the primary releases. There were 12 groups of hatchery yearling chinook salmon

Table 5. Number of juvenile salmonids captured by purse seine in Lower Granite Reservoir near Clarkston, Washington, 1995. Abbreviations: H-hatchery; W-wild.

Date	Sets	Chinook salmon H	Chinook salmon W	Steelhead H	Steelhead W	Sockeye salmon	Total
8 Apr	3	1,258	75	0	15	0	1,348
10 Apr	4	469	58	3	51	0	581
11 Apr	5	315	46	18	50	0	429
13 Apr	2	149	24	40	15	0	228
14 Apr	2	1,069	20	61	2	0	1,152
17 Apr	4	316	21	115	11	0	463
18 Apr	5	263	21	132	20	0	436
19 Apr	3	144	28	115	4	0	291
20 Apr	4	557	43	952	6	0	1,558
21 Apr	2	214	25	1,135	7	1	1,382
22 Apr	4	1,256	101	482	2	1	1,842
23 Apr	3	59	1	1,011	5	0	1,076
24 Apr	2	966	61	343	3	1	1,374
25 Apr	3	649	54	1,219	17	0	1,939
26 Apr	2	364	33	1,328	1	3	1,729
27 Apr	6	1,685	65	1,290	46	1	3,087
28 Apr	3	1,076	67	140	2	0	1,285
29 Apr	4	429	50	1,260	76	2	1,817
30 Apr	2	778	51	276	12	0	1,117
1 May	3	1,320	203	1,198	83	0	2,804
2 May	5	245	31	602	53	1	932
3 May	5	299	43	1,055	103	0	1,500
4 May	4	74	11	59	6	1	151
5 May	7	68	15	1,245	181	0	1,509
8 May	3	124	67	351	33	0	575
9 May	2	24	20	530	61	0	635
10 May	4	21	18	568	57	0	664
11 May	3	7	6	260	31	0	304
12 May	2	7	6	149	31	0	193
Total	101	14,205	1,264	15,937	984	11	32,401
% Mortality		0.3	0.0	0.1	0.0	0.0	0.2

Table 6. Number of nonsalmonids, adult chinook salmon, and adult steelhead captured by purse seine in Lower Granite Reservoir near the Port of Wilma and Silcott Island, 1995.

	Port of Wilma 8 April - 15 May 89 purse-seine sets	Silcott Island 22 April - 3 May 14 purse-seine sets	Total 8 April - 15May 103 purse-seine sets
Adult chinook salmon	1	0	1
Adult steelhead	36	5	41
Chiselmouth	4	0	4
Peamouth	13	0	13
Northern squawfish	8	1	9
Black crappie	299	258	557
Largescale sucker	21	1	22
Carp	22	0	22
All species	404	265	669

released between 9 April and 5 May and 11 groups of hatchery steelhead released between 22 April and 12 May.

Fish were in excellent condition, as indicated by the low mortality and small percentage rejected for tagging. Only 62 (0.4%) of 14,205 fin-clipped chinook salmon and 33 (0.2%) of 15,937 fin-clipped steelhead captured were rejected because of descaling or because they were previously PIT tagged. Overall mortality in the reservoir (handling and post-tagging combined) averaged 0.3% for hatchery yearling chinook sahnon and 0.1% for hatchery steelhead (Table 5). One or 2 days of purse seining were needed to capture fish for each release group. After PIT tagging, fish were held from 4 to 29 hours before release.

Lower Granite Dam

Fish for post-detection releases were PIT tagged at Lower Granite Dam from 17 April to 16 May. A total of 14,964 hatchery yearling chinook salmon, 6,075 wild yearling chinook salmon, 27,708 hatchery steelhead, and 1,443 wild steelhead were handled (Table 7). Mortality from handling and tagging averaged 1.9% for hatchery yearling chinook salmon, 0.7% for wild yearling chinook salmon, 0.1% for hatchery steelhead, and 0.0% for wild steelhead (Table 7).

Between 9 April and 1 July, a total of 104,296 hatchery yearling chinook salmon and 3 1,783 wild yearling chinook salmon were PIT tagged at Lower Granite Dam and released in Lower Granite Dam tailrace as part of a study to compare adult returns of fish that migrated through the hydropower system versus those that were transported around it. Information on the number of fish handled and marking/handling mortality can be found in the transportation evaluation annual report (Marsh et al. in prep.).

Table 7. Number of fish handled and mortalities at Lower Granite Dam during PIT tagging for 1995 survival studies.

Tag date	Hatchery chinook		Wild chinook		Hatchery steelhead		Wild steelhead	
	Handled	Mort.	Handled	Mort.	Handled	Mort.	Handled	Mort.
17 Apr	1,801	12	1,804	1	530	0	296	0
19 Apr	3,536	61	1,545	9	1,460	0	199	0
20 Apr	2,308	50	836	23	1,166	0	136	0
21 Apr	3,437	32	988	4	1,589	0	130	0
27 Apr	0	0	0	0	1,605	0	0	0
1 May	0	0	0	0	1,618	3	0	0
4 May	0	0	0	0	1,577	4	0	0
8 May	2,035	94	428	3	8,159	4	263	0
9 May	0	0	0	0	1,634	1	0	0
15 May	1,812	36	421	2	6,674	4	340	0
16 May	35	1	53	0	1,696	2	79	0
Total	14,964	286	6,075	42	27,708	18	1,443	0
% Mortality		1.9		0.7		0.1		0.0

Target numbers of PIT-tagged fish for each release at Lower Granite Dam were met on most release dates. However, for hatchery chinook salmon only four post-detection bypass and two turbine releases were made because of a lack of fish availability due to needs for fish for other concurrently conducted research. Releases of hatchery yearling chinook salmon were made primarily during the early and later parts of the hatchery chinook salmon migration, while releases of hatchery steelhead were made during the middle part of the hatchery steelhead migration (Fig. 6).

Little Goose Dam

Fish were PIT tagged at Little Goose Dam from 8 to 26 May. A total of 3,961 hatchery yearling chinook salmon, 666 wild yearling chinook salmon, 8,356 hatchery steelhead, and 465 wild steelhead were handled (Table 8). Mortality from handling and tagging averaged 0.8% for hatchery chinook salmon, 0.6% for wild yearling chinook salmon, 0.4% for hatchery steelhead, and 0.2% for wild steelhead (Table 8).

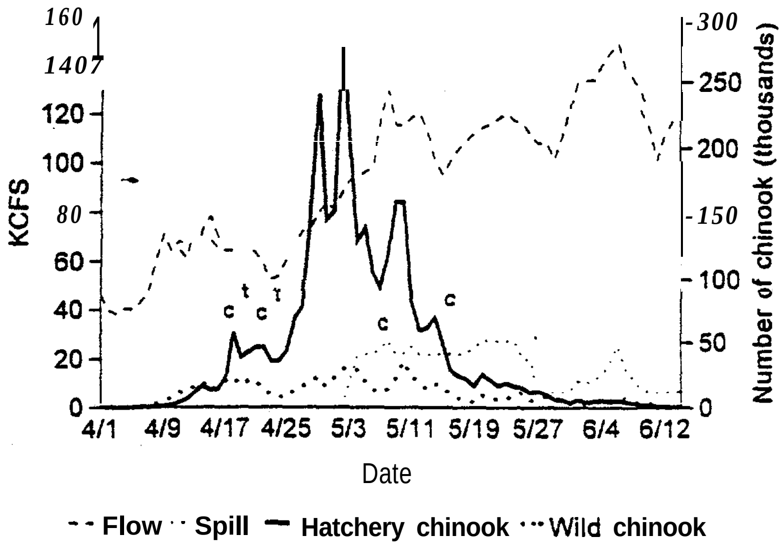
No releases of chinook salmon were made. Target numbers of PIT-tagged hatchery steelhead for each release at Little Goose Dam were met on most release dates. Releases were made during the middle and latter half of the migration (Fig. 7).

Lower Monumental Dam

Fish were PIT tagged at Lower Monumental Dam from 3 to 30 May. A total of 15,021 hatchery yearling chinook salmon, 3,385 wild yearling chinook salmon, 17,876 hatchery steelhead, and 1,648 wild steelhead were handled (Table 9). Mortality from handling and tagging

Lower Granite Dam

Chinook salmon



Steelhead

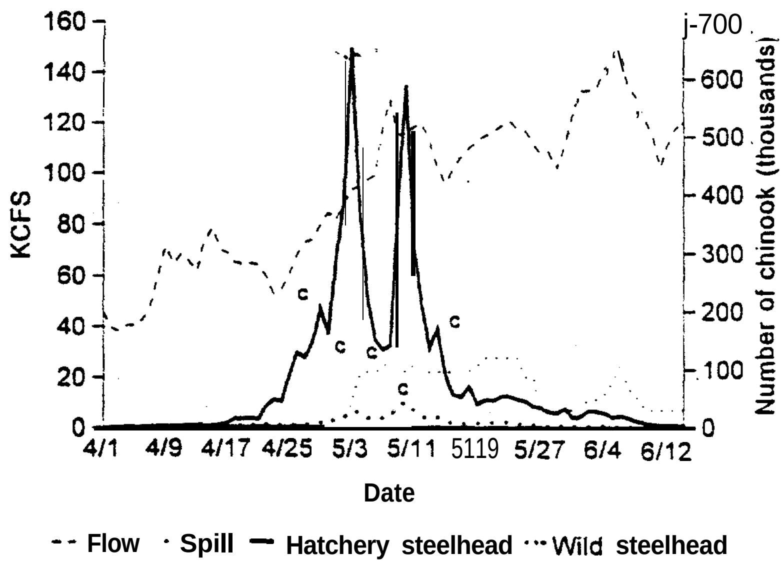


Figure 6. Yearling chinook salmon and steelhead passage at Lower Granite Dam during 1995 survival studies, Letters indicate paired releases (test and reference) for post-detection ("c") and turbine ("t") evaluation. Flow and spill are also shown.

Table 8. Number of fish handled and mortalities at Little Goose Dam during PIT tagging for 1995 survival studies.

Tag date	Hatchery chinook		Wild chinook		Hatchery steelhead		Wild steelhead	
	Handled	Mort.	Handled	Mort.	Handled	Mort.	Handled	Mort.
8 May	451	10	53	2	1,515	8	44	0
11 May	324	7	45	0	1,921	13	87	0
15 May	576	3	67	1	1,788	2	92	0
21 May	1,094	5	162	0	1,558	10	126	1
26 May	1,516	7	339	1	1,574	4	116	0
Total	3,961	32	666	4	8,356	37	465	1
% Mortality		0.8		0.6		0.4		0.2

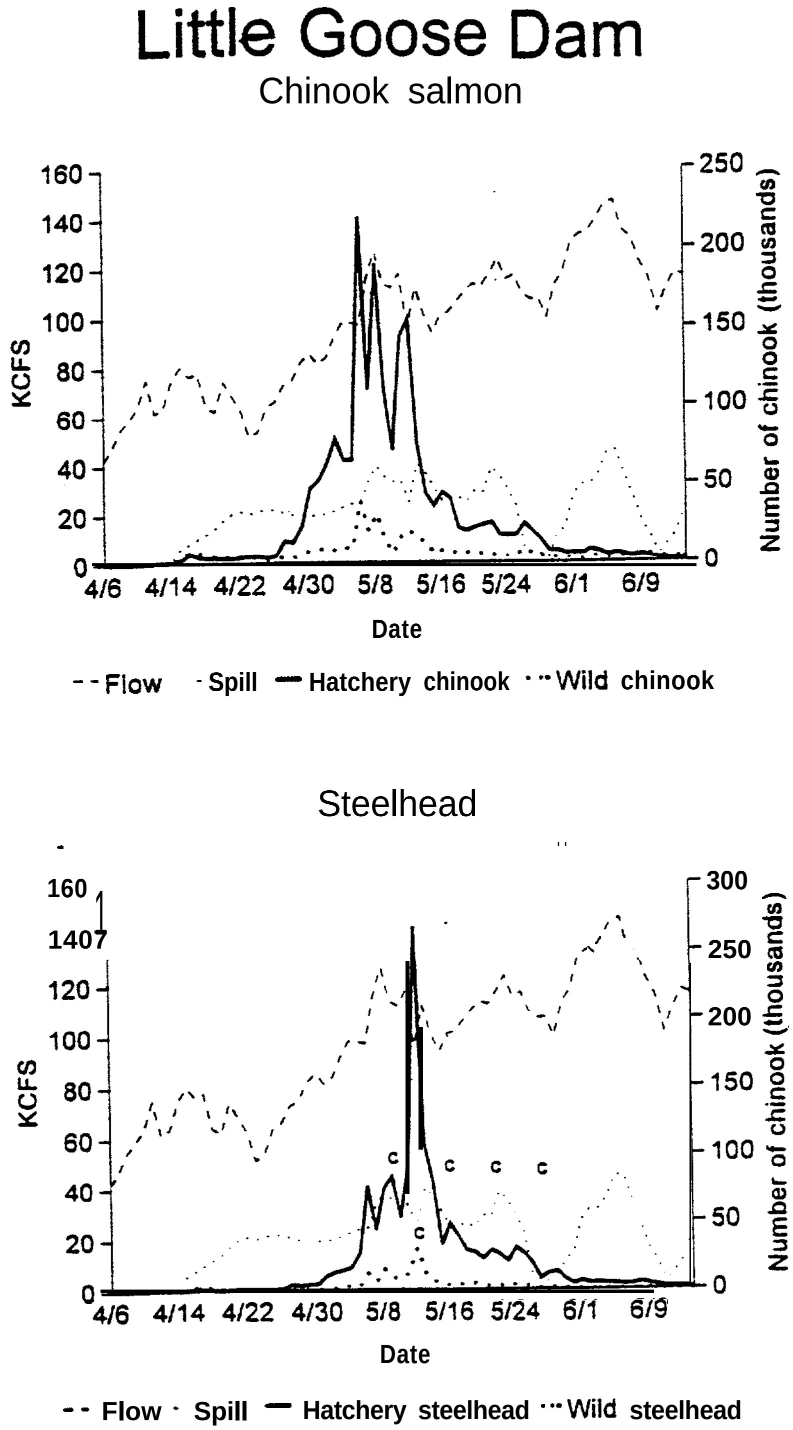


Figure 7. Yearling chinook salmon and steelhead passage at Little Goose Dam during 1995 survival studies. Letters indicate paired releases (test and reference) for post-detection ("c") and turbine ("t") evaluation. Flow and spill are also shown.

Table 9. Number of fish handled and mortalities at Lower Monumental Dam during PIT tagging for 1995 survival studies.

	Hatchery chinook		Wild chinook		Hatchery steelhead		Wild steelhead	
Tag date	Handled	Mort.	Handled	Mort.	Handled	Mort.	Handled	Mort.
3 May	2,870	17	509	4	1,297	2	56	0
6 May	2,146	14	714	3	716	1	247	0
9 May	852	5	406	0	1,751	0	337	0
12 May	1,385	8	219	3	3,185	5	159	0
14 May	1,639	19	324	2	1,637	1	303	0
16 May	1,196	8	147	2	1,853	9	63	0
18 May	1,383	10	245	0	2,114	15	66	0
20 May	1,782	4	317	0	1,203	1	252	0
25 May	1,154	0	277	0	1,975	11	95	0
30 May	614	0	227	0	2,145	15	70	0
Total	15,021	85	3,385	14	17,876	60	1,648	0
% Mortality		0.6		0.4		0.3		0.0

averaged 0.6% for hatchery chinook salmon, 0.4% for wild yearling chinook salmon, 0.3% for hatchery steelhead, and 0.0% for wild steelhead (Table 9).

Target numbers of PIT-tagged fish for each release at Lower Monumental Dam were met on most release dates. Hatchery yearling chinook salmon releases were made during the middle of the migration, while hatchery steelhead releases were made during the latter half of the hatchery steelhead migration (Fig. 8).

Tag Retention

PIT-tag retention was 100% for both yearling chinook salmon and steelhead held in Lower Granite Reservoir and at Lower Monumental Dam (Table 10). Tag retention was not measured at Lower Granite or Little Goose Dams during 1995. Because of the high tag-retention rate, no adjustments were made to the release numbers, and this resulted in very slight underestimation of the true survival probability.

Project Operations

Slide-Gate Operation

Between 29 March and 1 July, 55,598 PIT-tagged salmonids (all species) were detected at Lower Granite Dam. Of these, 47,899 (86.2%) were bypassed back to the Snake River by the slide-gate diverter system (Table 1 I). The remainder were either missed by the slide gate and transported (10.9%), removed prior to reaching the slide gate for the Smolt Monitoring Program (SMP) sample (1.6%), or were not detected again and their fate unknown (1.3%).

Lower Monumental Dam

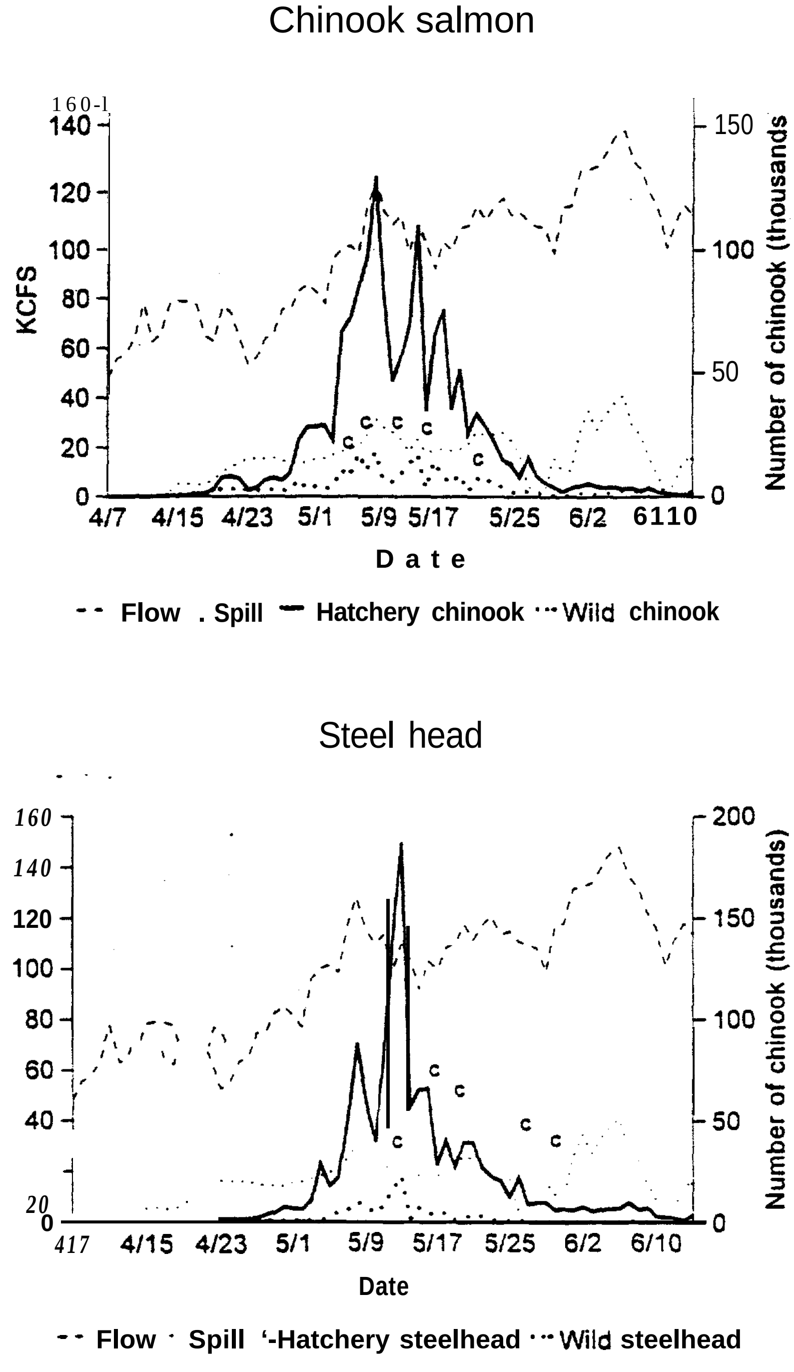


Figure 8. Yearling chinook salmon and steelhead passage at Lower Monumental Dam during 1995 survival studies. Letters indicate paired releases (test and reference) for post-detection ("c") and turbine ("t") evaluation. Flow and spill are also shown.

Table 10. Tag retention for hatchery yearling chinook salmon and steelhead PIT tagged in Lower Granite Reservoir (Res) and Lower Monumental Dam (LMO) during April and May, 1995. Fish were scanned for PIT tags after being held for 24 hours.

Location	Species	Tag date	Number held	Number untagged	Retention (%)
Res	Chinook	26 Apr	50	0	100.0
Res	Chinook	2 May	50	0	100.0
Res	Steelhead	29 Apr	50	0	100.0
Res	Steelhead	10 May	50	0	100.0
LMO	Chinook	15 May	55	0	100.0
LMO	Steelhead	30 May	65	0	100.0

Table 11 Number of PIT-tagged juvenile salmonids detected and diverted at Lower Granite (LGR Little Goose (LGO), Lower Monumental (LMO), and McNary (MCN) Dams during the 1995 migration (up to 1 July). Diverted fish were returned to the Snake or Columbia River; fish in the raceways and sample were transported out of the study-area.

Dam	Total detected	Diverted Number	Diverted (%)	Raceways Number	Raceways (%)	Sample Number	Sample (%)	Unknown Number	Unknown (%)
Yearling chinook salmon									
LGR	30,217	25,609	(84.8)	3,731	(12.3)	548	(1.8)	329	(1.1)
LGO	67,956	56,630	(83.3)	8,560	(12.6)	1,557	(2.3)	1,209	(1.8)
LMO	71,778	67,836	(94.5)	1,996	(2.8)	1,722	(2.4)	224	(0.3)
MCN	51,463	25,329	(49.2)	394	(0.8)	362	(0.7)	25,378	(49.3)
Steelhead									
LGR	23,757	21,120	(88.9)	2,192	(9.2)	290	(1.2)	155	(0.7)
LGO	16,160	13,357	(82.7)	2,334	(14.4)	347	(2.1)	122	(0.8)
LMO	23,990	22,793	(95.0)	441	(1.8)	703	(2.9)	53	(0.2)
MCN	8,961	3,639	(40.6)	8	(0.1)	1	(0.0)	5,313	(59.3)
All species									
LGR	55,598	47,899	(86.2)	6,080	(10.9)	883	(1.6)	736	(1.3)
LGO	86,274	71,439	(82.8)	11,040	(12.8)	1,938	(2.2)	1,857	(2.2)
LMO	99,240	93,264	(94.0)	2,520	(2.5)	2,422	(2.4)	1,034	(1.0)
MCN	62,677	30,136	(48.1)	407	(0.6)	380	(0.6)	3 1,754	(50.7)

At Little Goose Dam, 86,274 PIT-tagged salmonids were detected, with 71,439 (82.8%) bypassed back to the Snake River by the slide-gate diverter system (Table 11). The remainder were either missed by the slide gate and transported (12.8%), removed prior to'passing the slide gate as part of the SMP sample (2.2%), or were not detected again and their fate unknown (2.2%).

At Lower Monumental Dam, 99,240 PIT-tagged sahnonids were detected, with 93,264 (94.0%) bypassed back to the Snake River by the slide-gate diverter system (Table 11). The remainder were either missed by the slide gate and transported (2.5%), removed prior to passing the slide gate as part of the SMP sample (2.4%), or were not detected again and their fate unknown (1 .0%).

At McNary Dam, 62,677 PIT-tagged salmonids were detected, with 30,136 detected as they were bypassed back to the Columbia River by the slide-gate diverter system (Table 11). However, detectors on the return-to-river line at McNary Dam were off from 16 May until 20 June. Almost all of the fish passing during this period were returned to the river without being detected beyond the separator-gate detector. For purposes of survival estimation, all fish detected by the separator-gate detector but not by any other detector ("unknown fate" in Table 11) during this period were assumed to have returned to the river. During the period when the detector operated, 1.2% of the detected fish were either missed by the slide gate and transported or removed prior to passing the slide gate as part of the SMP sample.

Slide-gate efficiencies less than 90% at Lower Granite and Little Goose Dams were due in part to reduced reading efficiency of the new Destron/Fearing PIT tags used during 1995. The problem was identified on 19 April. By 1 May, interrogation systems at all detection sites were adjusted to increase slide-gate efficiency.

Turbine Load and Spill

PIT-tagged hatchery yearling chinook salmon and hatchery steelhead releases occurred at Lower Granite Dam during variable powerhouse discharge levels both before and after large spill volumes began on 4 May (Table 12, Fig. 6). Turbine operation in Unit 4 was set at 135 MW (within 1% of peak turbine efficiency curve) during turbine releases.

At Little Goose Dam, releases of PIT-tagged hatchery steelhead were made during variable powerhouse discharge and spill levels (Table 13, Fig. 7). At Lower Monumental Dam, hatchery yearling chinook salmon and hatchery steelhead releases were made during variable powerhouse discharge and spill levels (Table 14, Fig. 8).

Data Analysis

Database Quality Assurance/Control

Of the total of 32,408 hatchery yearling chinook salmon records in tagging files, 600 records were eliminated because fish were transported from the dam at which they were released (collection channel releases). Of the remaining 3 1,808 fish, 223 (0.7%) were eliminated because of handling mortality and 59 (0.2%) because of observation record anomalies. Of a total of 35,107 hatchery steelhead records in tagging files, 1,735 were eliminated because fish were transported from the dam at which they were released (collection channel releases). Of the remaining 33,372 fish, 78 (0.2%) were eliminated because of handling mortality and 59 (0.2%)

Table 12. Conditions at Lower Granite Dam during collection channel and reference releases of PIT-tagged hatchery yearling chinook salmon and steelhead during 1995. Daily average spill in parentheses.

Date	Turbine discharge (kcfs)	Spill (kcfs)	Forebay elevation (ft)	Tailrace elevation (ft)
Chinook salmon. collection channel releases				
18 Apr	63.7	0.0 (0.0)	733.3	635.5
21 Apr	64.2	0.0 (0.0)	733.3	634.6
9 May	118.7	1.4 (22.0)	733.5	636.5
16 May	100.4	0.0 (21.9)	733.5	638.3
Chinook salmon. reference releases				
18 Apr	63.7	0.0 (0.0)	733.3	635.5
21 Apr	60.5	0.0 (0.0)	733.3	634.4
9 May	117.4	4.3 (22.0)	733.4	636.4
16 May	97.2	0.0 (21.9)	733.4	638.2
Steelhead, collection channel releases				
28 Apr	73.7	0.0 (0.0)	733.5	634.3
2 May	90.2	010 (0.0)	733.5	635.2
5 May	99.4	0.0 (21.7)	733.2	635.5
10 May	113.8	0.0 (21.9)	133.2	636.2
17 May	94.0	0.0 (21.7)	733.2	638.2
Steelhead. reference releases				
28 Apr	73.0	0.0 (0.0)	733.4	634.4
2 May	89.2	0.0 (0.0)	733.4	635.2
5 May	93.8	0.0 (21.7)	733.2	635.2
10 May	113.2	0.0 (21.9)	733.2	636.1
17 May	94.6	0.0 (21.7)	733.5	638.4

Table 13. Conditions at Little Goose Dam during collection channel and reference releases of PIT-tagged hatchery steelhead during 1995. Daily average spill in parentheses.

Date	Turbine discharge (kcfs)	Spill (kcfs)	Forebay elevation (ft)	Tailrace elevation (ft)
<u>Steelhead. collection channel releases</u>				
9 May	98.9	20.3 (35.0)	633.5	539.3
12 May	9406.0	0.0 (24.7)	636.2	540.6
16 May	98.2	0.0 (25.2)	637.1	540.2
22 May	77.0	38.2 (38.5)	637.3	539.2
27 May	104.2	0.0 (2.9)	636.8	540.2
<u>Steelhead. reference releases</u>				
9 May	81.5	25.8 (35.0)	633.6	538.7
12 May	35.8	50.8 (24.7)	636.6	539.4
16 May	53.7	49.2 (25.2)	637.1	539.3
22 May	77.4	38.2 (38.5)	637.3	539.3
27 May	104.7	0.0 (2.9)	636.7	540.2

Table 14. Conditions at Lower Monumental Dam during collection channel and reference releases of PIT-tagged hatchery yearling chinook salmon and steelhead during 1995. Daily average spill in parentheses.

Date	Turbine discharge (kcfs)	Spill (kcfs)	Forebay elevation (ft)	Tailrace elevation (ft)
Chinook salmon. collection channel releases				
4 May	99.4	0.0 (18.1)	538.2	442.5
7 May	103.8	10.2 (24.6)	537.6	442.8
11 May	102.3	16.1 (23.8)	537.5	443.1
15 May	67.0	19.3 (18.5)	539.0	441.5
21 May	86.9	25.5 (24.9)	538.2	442.8
Chinook salmon. reference releases				
4 May	94.3	0.0 (18.1)	538.4	442.3
7 May	103.4	14.7 (24.6)	537.5	443.0
11 May	63.0	36.1 (23.8)	538.2	441.4
15 May	66.9	18.9 (18.5)	539.1	441.5
21 May	88.4	25.5 (24.9)	538.2	442.7
Steelhead. collection channel releases				
13 May	102.9	18.5 (23.2)	539.0	443.1
17 May	83.9	19.7 (18.6)	539.5	442.5
19 May	88.5	19.0 (21.1)	538.9	442.5
26 May	110.2	0.0 (4.5)	538.9	442.4
31 May	107.3	14.0 (10.8)	---	---
Steelhead, reference releases				
13 May	84.3	18.4 (23.2)	539.1	442.2
17 May	85.5	19.4 (18.6)	539.3	442.6
19 May	88.3	19.0 (21.1)	538.8	442.6
26 May	107.8	0.6 (4.5)	539.0	442.4
31 May	107.9	17.1 (10.8)	538.7	443.4

because of observation record anomalies. A complete record of fish eliminated from each release group can be found in Appendix Tables B.1 through B.8.

Tests of Assumptions

While assumptions of the SR and MSR Models were generally met by most releases, there were more assumption violations in 1995 than in 1993 or 1994 (see Appendix A for detailed results). The problems appeared related to a difference in time required to pass dams for detected and nondetected fish. A large portion of nondetected fish presumably passed via spillways when that route was available. Travel time data suggested that fish passing via spill passed faster than fish passing via the bypass system at Lower Granite Dam, and especially at Little Goose Dam.

Survival Estimation -- Primary Releases

Survival estimates for primary releases of hatchery yearling chinook salmon from the Port of Wilma to Lower Granite Dam tailrace ranged from 0.892 to greater than 1 .O (Table 15). The weighted average of the 12 survival estimates was 0.927 (se. 0.006). The weighted average survival estimate for Lower Granite Dam tailrace to Little Goose Dam tailrace was 0.900 (s.e. 0.015). The weighted average survival estimate from Little Goose Dam tailrace to Lower Monumental Dam tailrace was 0.939 (s.e. 0.016).

Table 15. Estimates of survival probabilities for hatchery yearling chinook salmon released near the Port of Wilma. Estimates based on the Single-Release Model. Standard errors in parentheses. Abbreviations: LGR-Lower Granite Dam; LGO-Little Goose Dam; LMO-Lower Monumental Dam.

Release	Date	Release to LGR (S_{R1})		LGR to LGO (S_{R2})		LGO to LMO (S_{R3})		Release to LMO	
R_{P1}	9 Apr	0.967	(0.029)	0.801	(0.043)	0.974	(0.072)	0.754	(0.047)
R_{P2}	11 Apr	0.938	(0.029)	0.856	(0.055)	0.954	(0.083)	0.766	(0.054)
R_{P3}	15 Apr	0.927	(0.026)	0.952	(0.051)	1.034	(0.089)	0.913	(0.066)
R_{P4}	18 Apr	0.892	(0.035)	0.875	(0.071)	0.899	(0.099)	0.702	(0.061)
R_{P5}	20 Apr	0.904	(0.026)	0.931	(0.053)	0.899	(0.074)	0.757	(0.050)
R_{P6}	23 Apr	0.920	(0.019)	0.956	(0.038)	0.905	(0.053)	0.796	(0.038)
R_{P7}	25 Apr	0.916	(0.020)	0.899	(0.037)	0.895	(0.053)	0.737	(0.036)
R_{P8}	27 Apr	0.909	(0.023)	0.913	(0.039)	1.044	(0.069)	0.866	(0.050)
R_{P9}	29 Apr	0.956	(0.030)	0.860	(0.045)	0.980	(0.069)	0.806	(0.048)
R_{P10}	1 May	0.952	(0.028)	0.943	(0.049)	0.911	(0.062)	0.818	(0.043)
R_{P11}	3 May	0.950	(0.059)	0.953	(0.104)	0.878	(0.117)	0.795	(0.077)
R_{P12}	5 May	1.013	(0.125)	0.743	(0.137)	0.916	(0.179)	0.689	(0.110)
Pooled*		0.927	(0.006)	0.900	(0.015)	0.939	(0.016)	0.785	(0.015)

* Pooled estimates are weighted averages of the independent estimates, with weights inversely proportional to the respective estimated variances.

Survival estimates for primary releases of hatchery steelhead from the Port of Wilma to Lower Granite Dam tailrace ranged from 0.894 to 0.947 with weighted average of 0.916 (s.e. 0.004) (Table 16). The weighted average survival estimates from Lower Granite Dam tailrace to Little Goose Dam tailrace and from Little Goose Dam tailrace to Lower Monumental Dam tailrace were 0.909 (s.e. 0.009) and 0.948 (s.e. 0.019), respectively.

The product of the three survival probability estimates provided an estimate of the probability of cumulative survival from release near the Port of Wilma to Lower Monumental Dam tailrace. The weighted average estimates were 0.785 (s.e. 0.015) and 0.796 (s.e. 0.012) for hatchery yearling chinook salmon and hatchery steelhead, respectively (Tables 15 and 16).

Detection rates at Little Goose and Lower Monumental Dams were affected in 1995 by the spill program (Tables 17 and 18). Detection rates at Lower Granite Dam decreased later in the season as spill increased. Detection rates for hatchery steelhead at Lower Granite Dam were as high as 0.851 (s.e. 0.012) before spill began and dropped to as low as 0.504 (s.e. 0.020) during the spill program. The chief effect of lower detection rates on the SR and MSR Models was decreased precision in estimating survival probabilities.

The weighted average survival estimate for passage of hatchery yearling chinook salmon through Turbine Unit 4 at Lower Granite Dam was 0.927 (s.e. 0.027) using the draft tube release as the reference (Table 19). The bypass outfall reference group did not mix evenly with the treatment group and was not used.

Table 16. Estimates of survival probabilities for hatchery steelhead released near the Port of Wilma. Estimates based on the Single-Release Model. Standard errors in parentheses. Abbreviations: LGR-Lower Granite Dam; LGO-Little Goose Dam; LMO-Lower Monumental Dam.

Release	Date	Release to LGR (S_{R1})		LGR to LGO (S_{R2})		LGO to LMO (S_{R3})		Release to LMO	
R_{P1}	22 Apr	0.913	(0.011)	0.880	(0.031)	0.960	(0.054)	0.771	(0.036)
R_{P2}	24 Apr	0.923	(0.012)	0.905	(0.033)	0.939	(0.059)	0.784	(0.042)
R_{P3}	26 Apr	0.917	(0.010)	0.907	(0.026)	0.911	(0.044)	0.758	(0.031)
R_{P4}	28 Apr	0.904	(0.011)	0.885	(0.029)	1.058	(0.068)	0.846	(0.049)
R_{P5}	30 Apr	0.894	(0.012)	0.915	(0.029)	1.008	(0.056)	0,825	(0.040)
R_{P6}	2 May	0.935	(0.019)	0.875	(0.036)	0.981	(0.064)	0.803	(0.044)
R_{P7}	4 May	0.907	(0.020)	0.948	(0.045)	0.906	(0.065)	0.779	(0.043)
R_{P8}	6 May	0.924	(0.017)	0.926	(0.035)	1.063	(0.072)	0.910	(0.052)
R_{P9}	9 May	0.947	(0.020)	0.905	(0.038)	0.920	(0.055)	0.788	(0.036)
R_{P10}	11 May	0.942	(0.019)	0.984	(0.039)	0.862	(0.052)	0.799	(0.037)
R_{P11}	12 May	0.910	(0.048)	0.959	(0.094)	0.841	(0.138)	0.734	(0.098)
Pooled*		0.916	(0.004)	0.909	(0.009)	0.948	(0.019)	0.796	(0.012)

* Pooled estimates are weighted averages of the independent estimates, with weights inversely proportional to the respective estimated variances.

Table 17. Estimates of detection probabilities for hatchery yearling chinook salmon released near the Port of Wilma. Estimates based on the Single-Release Model. Standard errors in parentheses. Abbreviations: LGR-Lower Granite Dam; LGO-Little Goose Dam; LMO-Lower Monumental Dam.

Release	Date	LGR	(P_1)	LGO	(P_2)	LMO	(P_3)
R_{P1}	9 Apr	0.428	(0.019)	0.360	(0.022)	0.378	(0.030)
R_{P2}	11 Apr	0.496	(0.024)	0.317	(0.026)	0.390	(0.035)
R_{P3}	15 Apr	0.421	(0.019)	0.323	(0.021)	0.342	(0.03 1)
R_{P4}	18 Apr	0.491	(0.029)	0.305	(0.031)	0.410	(0.045)
R_{P5}	20 Apr	0.524	(0.024)	0.374	(0.028)	0.472	(0.040)
R_{P6}	23 Apr	0.518	(0.018)	0.380	(0.020)	0.467	(0.029)
R_{P7}	25 Apr	0.507	(0.018)	0.406	(0.021)	0.475	(0.030)
R_{P8}	27 Apr	0.439	(0.018)	0.386	(0.021)	0.435	(0.932)
R_{P9}	29 Apr	0.376	(0.019)	0.388	(0.023)	0.444	(0.034)
R_{P10}	1 May	0.374	(0.018)	0.344	(0.021)	0.474	(0.032)
R_{P11}	3 May	0.315	(0.030)	0.271	(0.033)	0.432	(0.053)
R_{P12}	5 May	0.307	(0.057)	0.395	(0.069)	0.653	(0.142)

Table 18. Estimates of detection probabilities for hatchery steelhead released near the Port of Wilma. Estimates based on the Single-Release Model. Standard errors in parentheses. Abbreviations: LGR-Lower Granite Dam; LGO-Little Goose Dam; LMO-Lower Monumental Dam.

Release	Date	LGR (P_1)		LGO (P_2)		LMO (P_3)	
R_{P1}	9 Apr	0.843	(0.014)	0.389	(0.021)	0.577	(0.036)
R_{P2}	11 Apr	0.814	(0.015)	0.422	(0.023)	0.576	(0.042)
R_{P3}	15 Apr	0.851	(0.012)	0.451	(0.020)	0.642	(0.035)
R_{P4}	18 Apr	0.848	(0.013)	0.444	(0.021)	0.504	(0.038)
R_{P5}	20 Apr	0.775	(0.015)	0.449	(0.021)	0.581	(0.038)
R_{P6}	23 Apr	0.547	(0.018)	0.414	(0.022)	0.538	(0.039)
R_{P7}	25 Apr	0.549	(0.019)	0.365	(0.023)	0.562	(0.042)
R_{P8}	27 Apr	0.539	(0.017)	0.441	(0.021)	0.536	(0.042)
R_{P9}	29 Apr	0.527	(0.020)	0.407	(0.023)	0.677	(0.042)
R_{P10}	1 May	0.504	(0.020)	0.434	(0.024)	0.680	(0.045)
R_{P11}	3 May	0.542	(0.050)	0.486	(0.062)	0.609	(0.127)

Table 19. Survival estimates for hatchery yearling chinook salmon released in Turbine Unit 4 at Lower Granite Dam. Standard errors in parentheses. Abbreviations: LGR-Lower Granite Dam; LGG-Little Goose Dam.

Releases	Treatment group survival LGR to LGO tailrace	Reference group survival LGR to LGO tailrace	Turbine survival (S_{41})
(R_{411}, D_{411})	0.839 (0.032)	0.873 (0.055)	0.961 (0.071)
(R_{412}, D_{412})	0.813 (0.029)	0.898 (0.045)	0,905 (0.056)
Pooled*			0.927 (0.027)

* Pooled estimates are weighted averages of the independent estimates, with weights inversely proportional to the respective estimated variances.

Survival Estimation -- Lower Granite Dam Tailrace Releases

Survival probabilities were estimated by week for fish released in the tailrace at Lower Granite Dam for 12 consecutive weeks from 9 April through 1 July for hatchery and wild yearling chinook salmon (adult returns will be compared to fish transported as juveniles). Survival (weighted average) from Lower Granite Dam tailrace to Little Goose Dam tailrace averaged 0.883 (se. 0.006) for hatchery yearling chinook salmon (Table 20) and 0.877 (s.e. 0.012) for wild yearling chinook salmon (Table 21). From Little Goose Dam tailrace to Lower Monumental Dam tailrace, survival averaged 0.928 (s.e. 0.007) for hatchery yearling chinook salmon and 0.896 (s.e. 0.017) for wild yearling chinook salmon. For the entire reach (Lower Granite Dam tailrace to Lower Monumental Dam tailrace), survival averaged 0.822 (s.e. 0.007) for hatchery yearling chinook salmon and 0.793 (s.e. 0.019) for wild yearling chinook salmon.

From Lower Monumental Dam tailrace to McNary Dam tailrace, sufficient numbers of PIT-tagged fish were detected at John Day Dam to estimate survival for the first 5 weeks of releases (9 April through 13 May) (Table 20). Survival averaged 0.852 (se. 0.050) for hatchery yearling chinook salmon and 0.83 1 (s.e. 0.038) for wild yearling chinook salmon. Survival estimates for Lower Granite Dam tailrace to McNary Dam tailrace averaged 0.710 (se. 0.037) for hatchery yearling chinook salmon and 0.697 (s.e. 0.021) for wild yearling chinook salmon.

Nearly all hatchery yearling chinook salmon from the primary releases passed Lower Granite Dam by 13 May. The average survival estimates for hatchery yearling chinook salmon released into Lower Granite Dam tailrace between 9 April and 13 May were slightly lower than for the primary releases traversing the same river sections. However, differences were not significantly different. From Lower Granite Dam tailrace to Lower Monumental Dam tailrace

Table 20. Estimates of survival probabilities for hatchery yearling chinook released into the tailrace of Lower Granite Dam for comparison with transported smolts. Estimates based on the Single-Release Model. Standard errors in parentheses. Abbreviations: LGR-Lower Granite Dam; LGO-Little Goose Dam; LMO-Lower Monumental Dam; MCN-McNary Dam.

Dates	Number released	LGR to LGO (S_{R2})		LGO to LMO (S_{R3})		LMO to MCN (S_{R4})		LGR to MCN	
9-15 Apr	1,871	0.850	(0.038)	0.950	(0.067)	0.802	(0.223)	0.647	(0.176)
16-22 Apr	14,461	0.881	(0.0 15)	0.961	(0.025)	0.754	(0.091)	0.644	(0.077)
23-29 Apr	24,378	0.872	(0.008)	0.962	(0.016)	0.787	(0.079)	0.660	(0.066)
30 Apr-6 May	36,608	0.901	(0.006)	0.915	(0.010)	0.893	(0.060)	0.736	(0.049)
7-13 May	18,578	0.871	(0.009)	0.922	(0.015)	1.174	(0.166)	0.944	(0.132)
14-20 May	4,176	0.856	(0.022)	0.967	(0.045)	--es-		----e	
21-27 May	1,377	0.868	(0.036)	0.866	(0.076)	-----		-----	
28 May-3 Jun	1,234	0.895	(0.049)	0.848	(0.088)	-----		-----	
4-10 Jun	1,004	0.865	(0.023)	0.916	(0.05 1)				
11-17 Jun	250	0.987	(0.05 1)	0.863	(0.156)	-----		-----	
18-24 Jun	251	0.781	(0.046)	0.790	(0.091)	-----		-----	
25 Jun-1 Jul	108	0.723	(0.084)	0.873	(0.221)	-----		-----	
Pooled'	104,296	0.883	(0.006)	0.928	(0.007)	0.852	(0.050)	0.710	(0.037)

* Pooled estimates are weighted averages of the independent estimates, with weights inversely proportional to the respective estimated variances.

Table 21. Estimates of survival probabilities for wild yearling chinook released into the tailrace of Lower Granite Dam for comparison with transported smolts. Estimates based on the Single-Release Model. Standard errors in parentheses. Abbreviations: LGR-Lower Granite Dam; LGO-Little Goose Dam; LMO-Lower Monumental Dam; MCN-McNary Dam.

Dates	Number released	LGR to LGO (S_{R2})	LGO to LMO (S_{R3})	LMO to MCN (S_{R4})	Release to MCN
9-15 Apr	3,858	0.838 (0.015)	0.945 (0.034)	1.004 (0.195)	0.795 (0.152)
16-22 Apr	9,555	0.872 (0.023)	0.990 (0.037)	0.769 (0.079)	0.664 (0.066)
23-29 Apr	5,154	0.876 (0.016)	0.951 (0.032)	0.857 (0.187)	0.714 (0.154)
30 Apr-6 May	5,200	0.916 (0.012)	0.879 (0.020)	0.879 (0.129)	0.708 (0.103)
7-13 May	2,857	0.867 (0.017)	0.952 (0.031)	0.920 (0.230)	0.759 (0.188)
14-20 May	1,033	0.956 (0.040)	0.835 (0.059)	-----	-----
21-27 May	677	0.895 (0.034)	0.889 (0.070)	-----	-----
28 May-3 Jun	920	0.855 (0.027)	0.838 (0.048)	-----	-----
4-10 Jun	1,222	0.907 (0.015)	0.875 (0.030)	-----	-----
11-17 Jun	494	0.875 (0.027)	0.792 (0.051)	-----	-----
18-24 Jun	571	0.806 (0.025)	0.808 (0.040)	-----	
25 Jun-1 Jul	242	0.696 (0.043)	0.772 (0.082)	-----	-----
Pooled*	31,783	0.877 (0.012)	0.896 (0.017)	0.831 (0.038)	0.697 (0.021)

* Pooled estimates are weighted averages of the independent estimates, with weights inversely proportional to the respective estimated variances.

(two dams and reservoirs), the average survival estimate for primary releases was 0.845 (s.e. 0.015), versus 0.825 (s.e. 0.007) for Lower Granite Dam tailrace releases during the comparable period.

Survival estimates for daily release groups are given in Appendix C.

Survival Estimation -- Hatchery Releases

Preliminary analyses to determine the composition of pooled release groups are summarized below.

1) Dworshak National Fish Hatchery (NFH): In the evaluation of a new antibiotic treatment on yearling chinook salmon, parameter estimates for the control group of 800 fish differed significantly from those for the 4 treatment groups. Only the control group was used for survival estimation. Among the roughly 4,500 steelhead released from the hatchery between 24 and 28 April, those identified as "early return progeny" differed significantly from the rest and were omitted from the analysis, leaving 4,232 fish. Clear Creek and Clearwater River releases did not differ and were pooled into a single group of 644 fish for survival estimation.

2) Kooskia National Fish Hatchery: The two releases of yearling chinook salmon from the hatchery did not differ significantly and were pooled into a single group of 1,201 fish. The Clear Creek release was analyzed separately.

3) Lookingglass Hatchery: Release groups were classified according to release site and release date, producing 5 release groups, each with significant differences from the others.

4) McCall Hatchery: Releases were made for a variety of reasons on 6 and 7 April, but these groups had no significant differences among their parameters. These "early" releases were

pooled into a single group of 6,298 fish, and analyzed separately from the other time-of-release study groups.

5) Rapid River Hatchery: Hand- and auto-tagged yearling chinook salmon groups released from the hatchery on 3 1 March were analyzed separately. The Hells Canyon release on 30 March was also kept separate.

6) Sawtooth Hatchery: Parameters for the release groups of yearling chinook salmon in the Salmon River and the East Fork of the Salmon River did not differ significantly. Therefore, releases were pooled into a single group of 1,289 fish. The pooled group differed significantly from the group of 1,499 released from the hatchery.

7) Pahsimeroi Hatchery: Only one release of 493 fish was made from this hatchery.

For hatchery-released fish, estimated survival probabilities from the point of release to Lower Granite Dam tailrace ranged from 0.087 to 0.842 (Table 22). Although sample sizes and standard errors for the survival probability estimates from release to Lower Granite Dam tailrace were comparable to those for our primary releases, survival probability estimates were lower and generally appeared to be inversely proportional to the distance from the release point to Lower Granite Dam.

Because the river section is the same, survival probability estimates from Lower Granite Dam tailrace to Little Goose Dam taiirace and from Little Goose Dam tailrace to Lower Monumental Dam tailrace for hatchery releases are directly comparable to those for our primary releases. The weighted average estimate from the hatchery releases of yearling chinook salmon from Lower Granite Dam tailrace to Little Goose Dam tailrace was 0.911 (s.e. 0.008); comparable to the pooled estimate obtained from our primary releases of 0.900 (s.e. 0.015).

Table 22. Survival estimates for yearling chinook salmon and steelhead released from hatcheries. Estimates based on the Single-Release Model. Standard errors in parentheses. Abbreviations: Ch-yearling chinook; St-steelhead; LGR-Lower Granite Dam; LGO-Little Goose Dam; LMO-Lower Monumental Dam.

Hatchery	Release site	Sp.	Date	Rel. size	Release to LGR (S_H)	LGR to LGO (S_{R2})	LGO to LMO (S_{R3})	Release to LMO
Dworshak	Dworshak NFH	Ch	14 Apr	800	0.842 (0.034)	0.900 (0.064)	0.903 (0.084)	0.685 (0.050)
Dworshak	Clear C. and Cleanvater R.	St	17 Apr	644	0.728 (0.020)	0.956 (0.053)	1.051 (0.102)	0.732 (0.061)
Dworshak	Dworshak NFH	St	24-28 Apr	4,232	0.773 (0.007)	0.923 (0.0 14)	0.955 (0.026)	0.682 (0.017)
Kooskia	Kooskia H	Ch	12 Apr	1,201	0.791 (0.024)	0.871 (0.042)	0.898 (0.057)	0.690 (0.020)
Kooskia	Clear C.	Ch	12 Apr	494	0.583 (0.047)	0.783 (0.080)	1.003 (0.1 14)	0.458 (0.049)
Lookingglass"	Imnaha Weir	Ch	28 Mar	2,487	0.623 (0.0 15)	0.927 (0.037)	0.905 (0.056)	0.523 (0.028)
		Ch	5 Apr	493	0.469 (0.040)	0.775 (0.092)	0.864 (0.133)	0.3 14 (0.044)
		Ch	24-26 Apr	983	0.48 1 (0.034)	0.845 (0.123)	0.949 (0.114)	0.386 (0.041)
Lookingglass[b]	Lookingglass H	Ch	6 Apr	1,983	0.758 (0,019)	0.925 (0.037)	0.913 (0.055)	0.640 (0.033)
Lookingglass"	Big Canyon	Ch	21 Apr	114	0.800 (0,054)	0.876 (0.123)	0.890 (0.202)	0.624 (0.117)
McCall	Knox Bridge	Ch	6-7 Apr	6,298	0.523 (0.012)	0.894 (0.026).	0.875 (0.033)	0.409 (0.014)
			19 Apr	800	0.47 1 (0.034)	0.855 (0.072)	0.904 (0.099)	0.364 (0.038)
			24 Apr	400	0.478 (0.045)	0.954 (0.122)	1.056 (0.272)	0.481 (0.114)

Table 22. Continued.

Hatchery	Release site	Sp.	Date	Rel. size	Release to LGR (S_H)	LGR to LGO (S_{R2})	LGO to LMO (S_{R3})	Release to LMO
Rapid River	Rapid River H	Ch	31 Mar[d]	999	0.697 (0.024)	0.927 (0.046)	0.896 (0.062)	0.579 (0.035)
			31 Mar[e]	990	0.755 (0.026)	0.852 (0.047)	0.806 (0.057)	0.518 (0.031)
Rapid River	Hell's Canyon	Ch	30 Mar	499	0.582 (0.030)	1.016 (0.088)	0.984 (0.149)	0.581 (0.054)
Pahsimeroi	Pahsimeroi Pon	Ch	12 Apr	493	0.316 (0.038)	0.945 (0.147)	0.682 (0.138)	0.203 (0.034)
Sawtooth	Sawtooth H	Ch	5-7 Apr	1,499	0.231 (0.019)	0.916 (0.071)	1.040 (0.105)	0.220 (0.023)
Sawtooth	Salmon R and E. Fork Salmon	Ch	27-28 Mar	1,289	0.087 (0.021)	0.999 (0.231)	0.699 (0.162)	0.061 (0.016)
Pooled		Ch			-----	0.911 (0.008)	0.912 (0.014)	-----

[a] Imnaha stock.

[b] Rapid River stock.

[c] Irrigon stock.

[d] Hand-injected PIT tags.

[e] Auto-injected PIT tags.

[f] Pooled estimates are weighted averages of the independent estimates from releases of yearling chinook salmon, with weights inversely proportional to the respective estimated variances.

From Little Goose Dam tailrace to Lower Monumental Dam t&ace, the weighted average survival estimates were 0.912 (s.e. 0.014) and 0.939 (s.e. 0.016) for the hatchery releases and our primary releases, respectively. Releases with the lowest survival probability between the hatchery and Lower Granite Dam tailrace often had higher probability of survival between the tailraces of Lower Granite and Little Goose Dams.

Survival Estimation -- Fish Trap Releases

Survival estimates for hatchery chinook salmon released from the Snake River and Clear-water River traps were slightly lower than for our primary releases (Table 23). From release to Lower Granite Dam tailrace, survival estimates were 0.891 (s.e. 0.022) for the Clear-water River trap and 0.906 (s.e. 0.015) for the Snake River trap, compared to the average estimate of 0.927 (se. 0.006) for our primary releases.. From release to Lower Monumental Dam tailrace, survival estimates were 0.750 (s.e. 0.038) for the Clear-water River trap, 0.721 (se. 0.026) for the Snake River trap, and 0.785 (se. 0.015) for our primary releases. For hatchery chinook salmon released from the Salmon River trap, survival estimates were 0.821 (se. 0.020) from the trap to Lower Granite Dam tailrace and 0.656 (s.e. 0.026) from the trap to Lower Monumental Dam tailrace.

Hatchery steelhead released from the Clearwater River and Snake River traps had slightly higher survival estimates to Lower Granite Dam tailrace (Table 23) than the average of our primary releases. Survival estimates from release to Lower Monumental Dam tailrace were 0.853 (s.e. 0.068) for the Clear-water River trap, 0.759 (s.e. 0.032) for the Snake River trap,

Table 23. Estimates of survival probabilities for juvenile salmonids released from fish traps in Snake River Basin during same period as primary releases. Estimates based on the Single-Release Model. Standard errors in parentheses. Abbreviations: LGR-Lower Granite Dam; LGO-Little Goose Dam; LMO-Lower Monumental Dam.

Trap	Release dates	Numbe r released	Release to LGR	LGR to LGO (S_{R2})	LGO to LMO (S_{R3})	Release to LMO
<u>Hatcherv chinook salmon</u>						
Salmon	10 Apr - 5 May	2,186	0.821 (0.020)	0.884 (0.033)	0.904 (0.043)	0.656 (0.026)
Cleat-water	9 Apr - 3 May	1,578	0.891 (0.022)	0.863 (0.036)	0.976 (0.058)	0.750 (0.038)
Snake	9 Apr - 5 May	2,343	0.906 (0.015)	0.900 (0.028)	0.885 (0.039)	0.721 (0.026)
<u>Wild chinook salmon</u>						
Salmon	10 Apr - 5 May	1,643	0.897 (0.015)	0.904 (0.025)	0.965 (0.038)	0.783 (0.027)
Cleat-water	9 Apr - 3 May	511	0.889 (0.034)	0.947 (0.068)	0.902 (0.098)	0.760 (0.068)
Snake	9 Apr - 5 May	1,122	0.973 (0.019)	0.903 (0.037)	0.945 (0.057)	0.831 (0.041)
<u>Hatcherv steelhead</u>						
Salmon	24 Apr - 13May	972	0.913 (0.016)	0.875 (0.029)	0.990 (0.054)	0.791 (0.038)
Cleat-water	24 Apr - 3 May	415	0.939 (0.020)	0.88 1 (0.046)	1.031 (0.092)	0.853 (0.068)
Snake	22 Apr - 12May	1,149	0.932 (0.013)	0.850 (0.027)	0.958 (0.046)	0.759 (0.032)
<u>Wild steelhead</u>						
Salmon	24 Apr- 13 May	315	0.877 (0.029)	0.980 (0.056)	0.93 1 (0.090)	d.801 (0.103)
Cleat-water	24 Apr - 3 May	48	0.896 (0.063)	0.810 (0142)	0.933 (0.204)	0.677 (0.123)
Snake	22 Apr - 12May	1,157	0.963 (0.014)	0.896 (0.029)	0.903 (0.045)	0.780 (0.033)

0.791 (s.e. 0.038) for the Salmon River trap, and an average of 0.796 (s.e. 0.012) for our primary releases of hatchery steelhead.

Wild yearling chinook had considerably higher survival estimates than their hatchery-reared counterparts released from the Salmon (12.7% higher from release to Lower Monumental Dam tailrace) and Snake River (11.0% higher) traps (Table 23). Wild and hatchery yearling chinook released from the Clear-water River trap had similar survival estimates. This pattern was reversed for steelhead. Wild steelhead had lower survival estimates than hatchery-reared for Clearwater River trap releases, and nearly the same survival estimates for Salmon and Snake River trap releases.

Travel Time

Travel time and migration rate statistics are given for all primary releases in Appendix Tables D1 through D10.

For the 12 primary releases of hatchery yearling chinook salmon, median migration rates from time of release at the Port of Wilma to detection at Lower Granite Dam (49 km) ranged from 3.1 to 9.1 km/day (Fig. 9). From Lower Granite Dam to Little Goose Dam (60 km), median migration rates ranged from 9.3 to 15.4 km/day (Fig. 10). From Little Goose Dam to Lower Monumental Dam (46 km), median migration rates ranged from 17.6 to 26.0 km/day (Fig. 11). From Lower Monumental Dam to McNary Dam (119 km), median migration rates ranged from 26.3 to 34.3 km/day (Fig. 12). For the entire river section from release at the Port of Wilma to

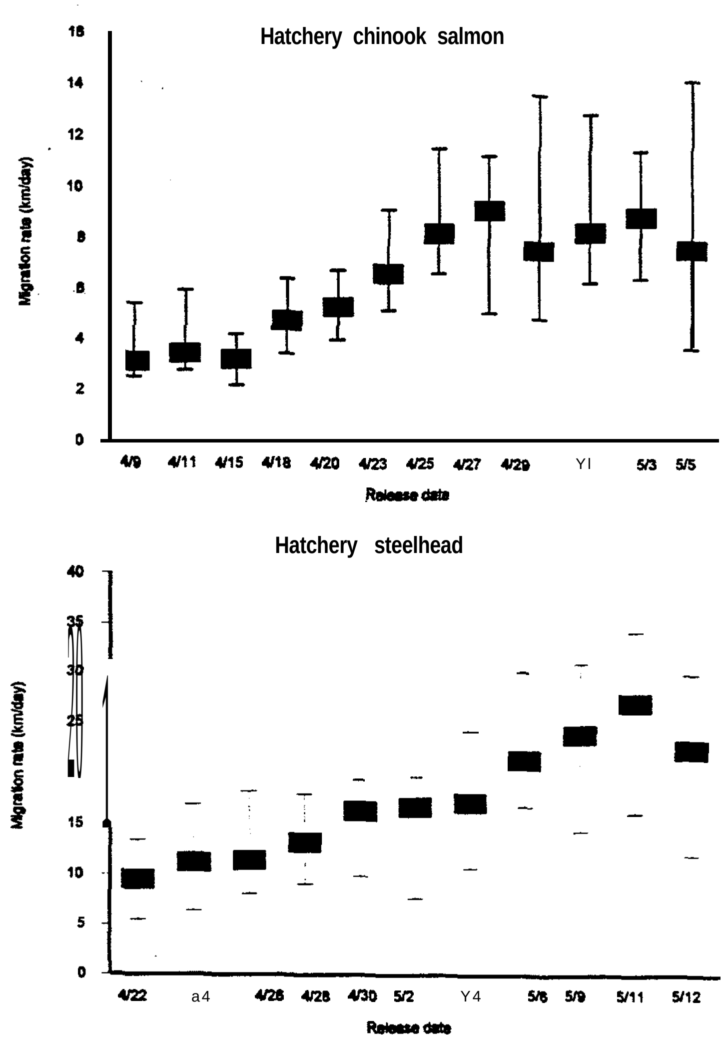


Figure 9. Median migration rate (km/day) from release near the Port of Wilma to Lower Granite Dam (49 km) for PIT-tagged hatchery chinook salmon and steelhead. Ends of thin lines show the 20th and 80th percentiles.

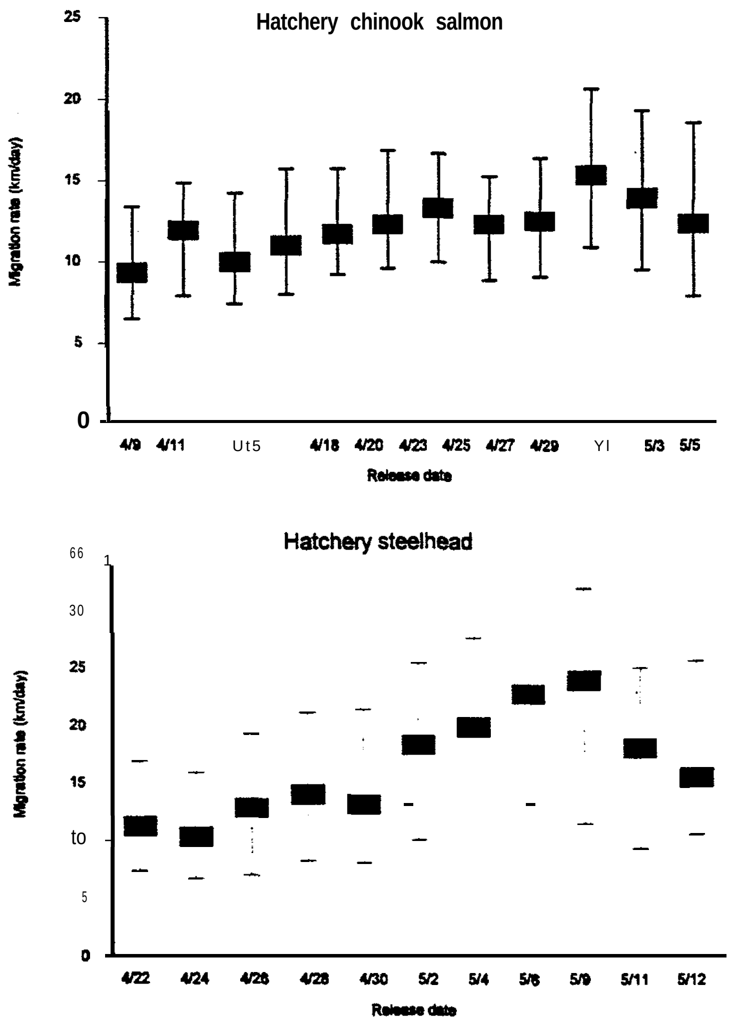


Figure 10. Median migration rate (km/day) from Lower Granite Dam to Little Goose Dam (60 km) for PIT-tagged hatchery chinook salmon and steelhead. Ends of thin lines show 20th and 80th percentiles.

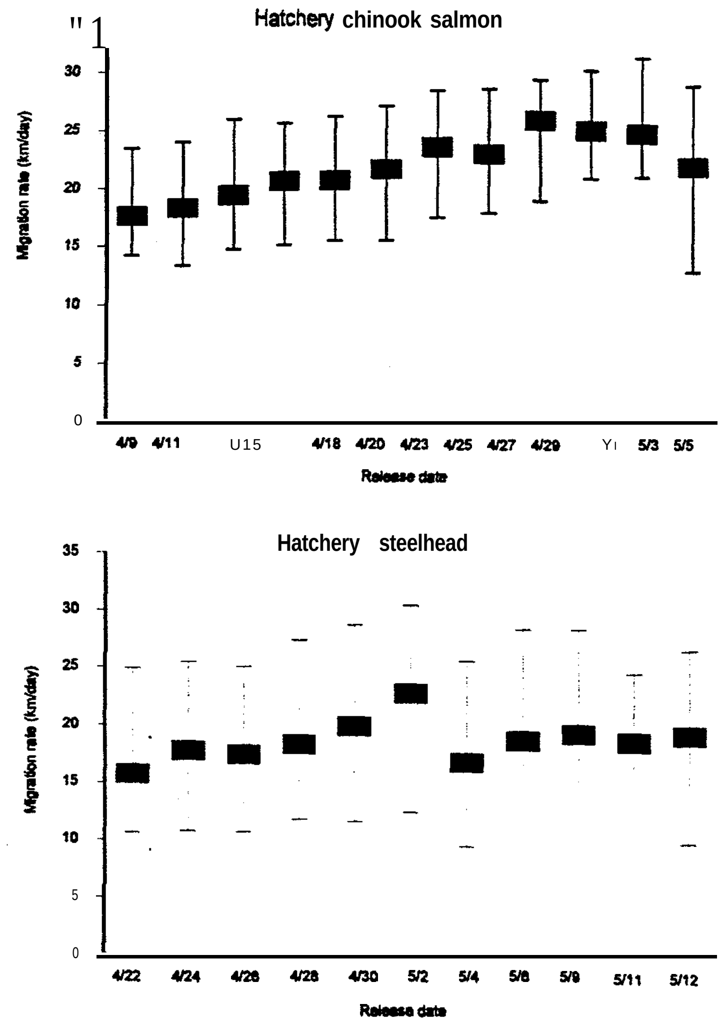


Figure 11. Median migration rate (km/day) from Little Goose Dam to Lower Monumental Dam (46 km) for PIT-tagged hatchery chinook salmon and steelhead. Ends of thin lines show 20th and 80th percentiles.

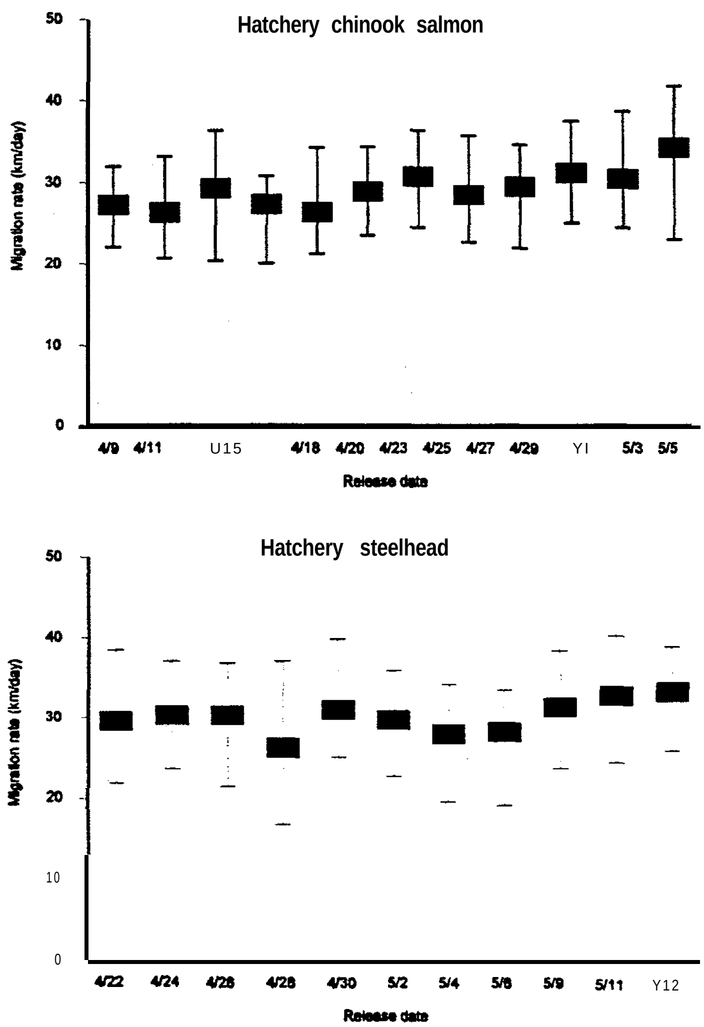


Figure 12. Median migration rate &m/day) from Lower Monumental Dam to McNary Dam (119 km) for PIT-tagged hatchery chinook salmon and steelhead. End of thin lines show 20th and 80th percentiles.

the final PIT-tag detector at McNary Dam, median migration rates ranged from 9.4 to 20.0 km/day (Fig. 13). The number of fish used to calculate travel times decreased as spill increased.

For the 11 primary releases of PIT-tagged hatchery steelhead, migration rates from the Port of Wilma to Lower Granite Dam ranged from 9.5 to 26.9 km/day (Fig. 9). From Lower Granite to Little Goose Dam, median migration rates ranged from 10.4 to 23.8 km/day (Fig. 10). From Little Goose to Lower Monumental Dam, median migration rates ranged from 15.7 to 22.8 km/day (Fig. 11). From Lower Monumental to McNary Dam, median migration rates ranged from 26.3 to 33.2 km/day (Fig. 12). For the entire river section from release at the Port of Wilma to the final PIT-tag detector at McNary Dam, median migration rates ranged from 14.9 to 26.6 km/day (Fig. 13).

For both hatchery yearling chinook salmon and hatchery steelhead, migration rates were highest in the lower river sections. Migration rates generally increased over time as flows, water temperatures, and levels of spill increased, and as fish presumably became more smolted. With this study, we were unable to differentiate between migration rates through individual reservoirs and delays before passing dams.

During the peak of the migration season, wild yearling chinook salmon released into the tailrace at Lower Granite Dam had travel times between Lower Granite and McNary Dams almost identical to their hatchery-reared counterparts (Fig. 14). Early in the season, wild fish traveled slower than hatchery fish, while travel times were short for wild fish late in the season. Within shorter reaches, for example between Lower Granite and Little Goose Dams, travel times were almost identical for wild and hatchery yearling chinook salmon across the entire season.

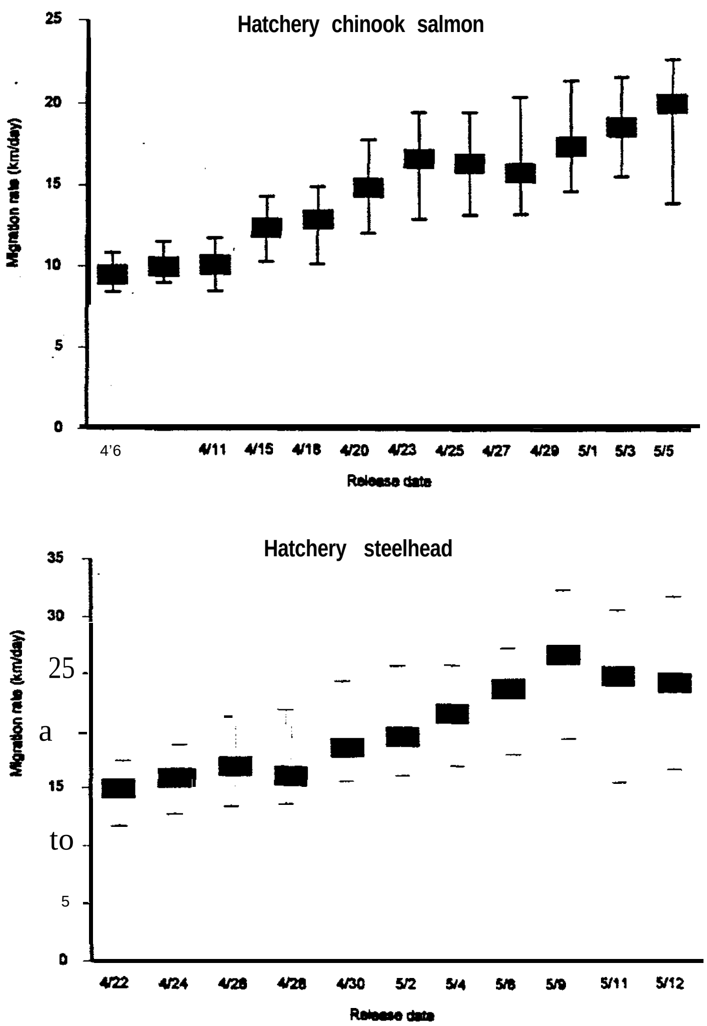


Figure 13. Median migration rate (km/day) from release near the Port of Wilma to McNary Dam (274 km) for PIT-tagged hatchery chinook salmon and steelhead. Ends of thin lines show 20th and 80th percentiles.

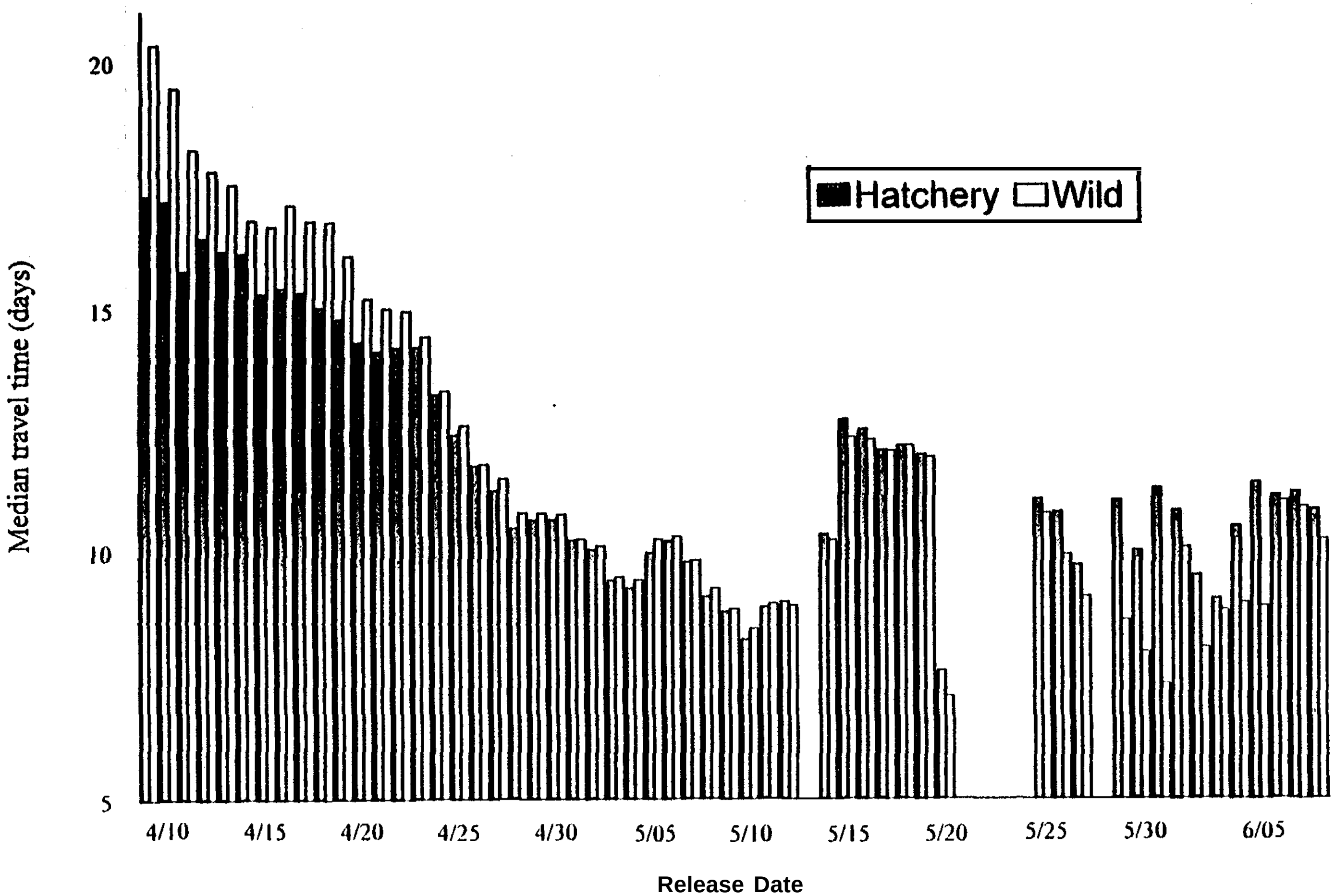


Figure 14. Median travel time (days) between Lower Granite and McNary Dams for daily releases of wild and hatchery yearling chinook salmon into Lower Granite Dam tailrace.

Comparison of Survival and Travel Time Estimates, 1993-1995

During the 1995 transportation evaluation, an attempt was made to PIT tag a constant proportion of migrants arriving at Lower Granite Dam so that adult return rates would be representative of the entire juvenile migration. For the survival study, the goal was to PIT tag sufficient numbers of migrants for each release to estimate survival (with minimal standard error) during the major portion of the migration. Survival estimates were similar in downstream reaches for hatchery yearling chinook salmon from the two studies. Furthermore, there was little within-year variation in estimates of survival for both hatchery yearling chinook salmon and steelhead each year. Although the survival estimates from this study do not represent the entire migration each year, their similarity to the transportation evaluation survival estimates (which do), and lack of within-year variability make between-year comparisons reasonable.

Primary releases were made near the head of Lower Granite Reservoir from Nisqually John Landing in 1993 (RKm 726), from Siicott Island in 1994 (RKm 732), and from the Port of Wilma in 1995 (RKm 744). Seven groups of hatchery yearling chinook salmon were released in 1993, 10 groups in 1994, and 12 groups in 1995. Survival (weighted average) was highest for hatchery yearling chinook salmon in 1995 in all reaches (Table 24).

Hatchery steelhead were released from Silcott Island in 1994 (9 groups) and from the Port of Wilma in 1995 (11 groups). Hatchery steelhead also had the highest survival in all reaches in 1995 (Table 24).

Plows (seasonal average) over the 3-year period were highest during 1993 and lowest during 1994 (Fig. 15). Flows in 1993 and 1995 were similar throughout much of April, but flow in May was much higher in 1993. The proportion of total flow spilled during the peak of hatchery

Table 24. Pooled estimates of survival from Nisqually John Landing (1993), Silcott Island (1994), and the Port of Wilma (1995) to Lower Granite (LGR), Little Goose (LGO), and Lower Monumental (LMO) Dam tailraces. Standard errors in parentheses.

	Release to LGR	LGR to LGO	LGO to LMO	Release to LMO
		Hatchery yearling chinook salmon		
1993	0.902 (0.008)	0.862 (0.013)	---	---
1994	0.922 (0.010)	0.794 (0.026)	0.891 (0.023)	0.659' (0.009)
1995	0.927 (0,007)	0.900 (0.015)	0.939 (0.016)	0.785 (0.015)
		Hatcherv steelhead		
1994	0.904 (0.007)	0.784 (0.012)	0.831 (0.013)	0.598 (0.012)
1995	0.916 (0.004)	0.909 (0.009)	0.948 (0.019)	0.796 (0.012)

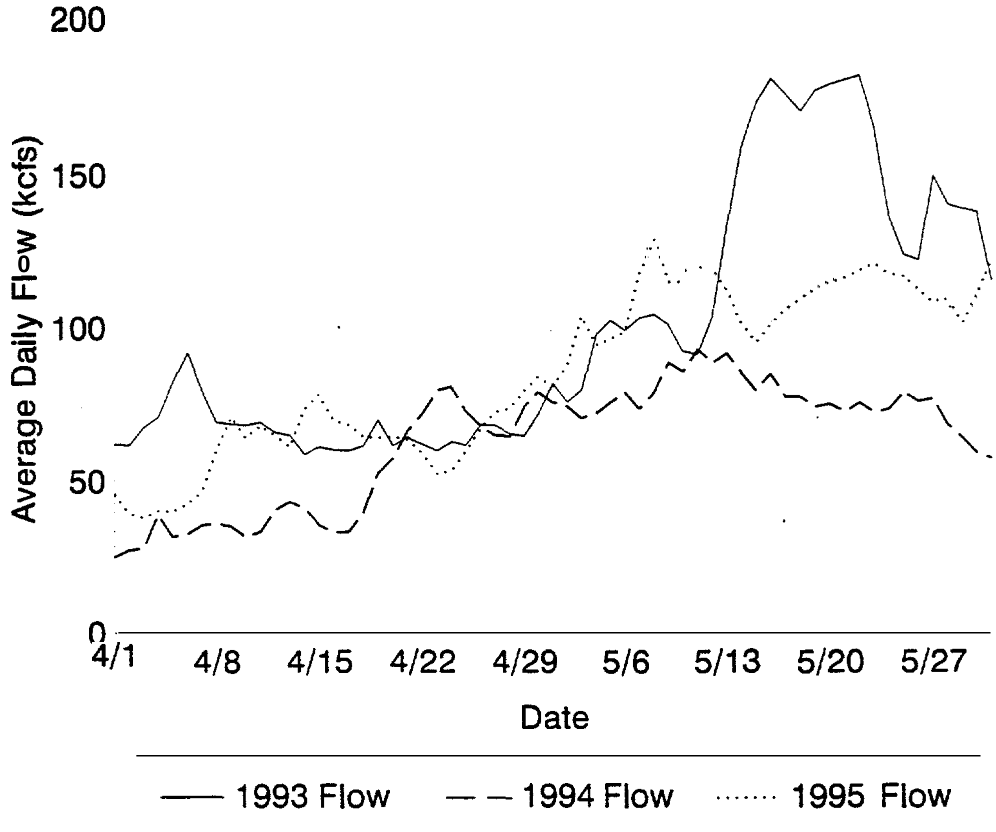


Figure 15. Average daily flow (kcfs) at Lower Granite Dam from 1 April through 31 May for 1993, 1994. and 1995.

yearling chinook salmon migration was highest in 1995, which might account for the increased survival observed during that year (Fig. 16). Spill was also high in 1993 and 1994, but occurred latter in the season, after many fish had passed. Spill could increase survival by increasing the proportion of fish that avoid turbine passage, the passage route associated with highest mortality.

Determining the relationship between flow and survival from these data is difficult because each of the primary releases migrated through a particular reach for an extended period under variable flow conditions. Spill further complicates analysis by altering survival rates depending on the route of passage. For example, fish passing through a reach under low or moderate flow levels with high levels of spill could have higher survival rates than fish passing during high flow levels with little or no spill. Furthermore, as flows increase in spring, water temperatures and smolt development usually increase. All of these factors influence smolt travel time and presumably survival. Since these factors are interrelated, isolating a single variable and its effect on smolt survival is difficult. Results of continuing analyses of this topic will be published in later reports and peer-reviewed articles.

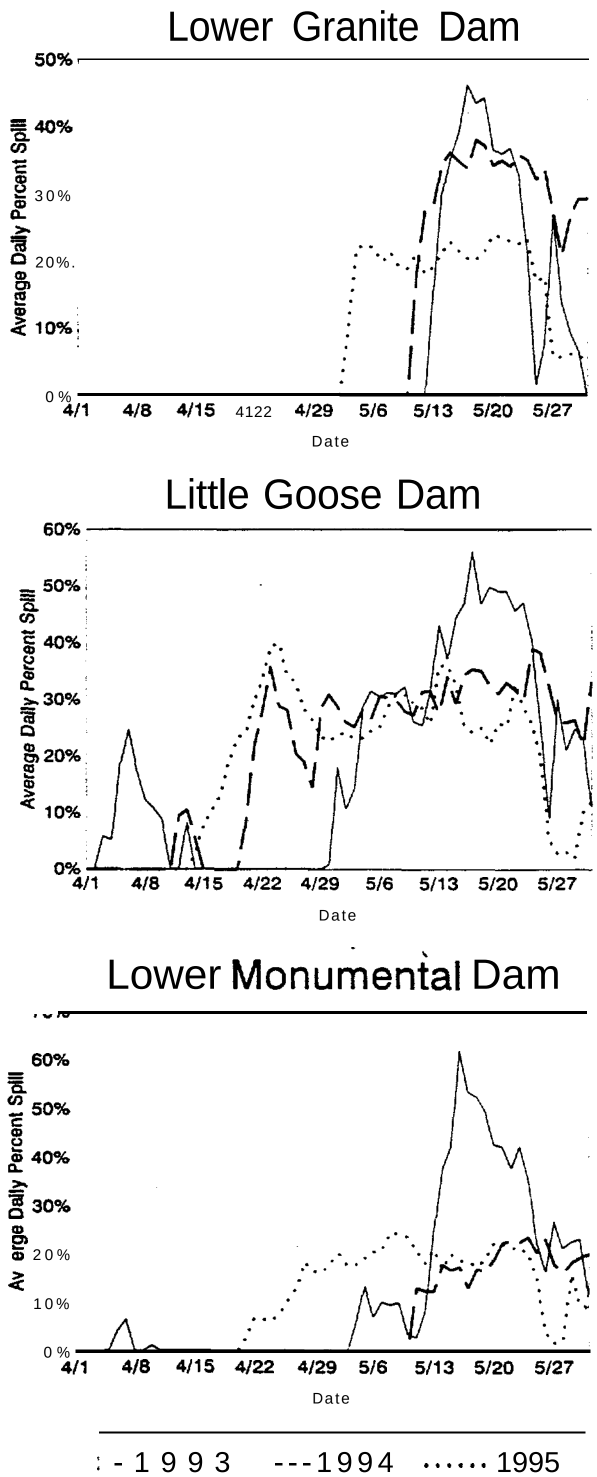


Figure 16. Average daily percent spill at Lower Granite, Little Goose, and Lower Monumental Dams from 1 April through 3 1 May for 1993, 1994, and 1995.

DISCUSSION

Results of the 1995 NMFS/UW survival study met the following specific research objectives: 1) to field test and evaluate the Single-Release, Modified Single-Release, and Paired-Release Models for estimating survival probabilities through sections of a river and hydroelectric projects with high precision; 2) to identity operational and logistical constraints that limit the ability to collect data for the models; and 3) to obtain under extant river conditions and dam operations, estimates of survival of juvenile chinook salmon and steelhead from their point of release to the tailrace of Lower Monumental Dam.

The SR Model was used in all analyses because no significant post-detection mortality occurred after fish were detected in the bypass system and before they remixed with fish using other passage routes. Further, although not all release groups were perfectly mixed, tests designed to assess lack of model fit of the type that could be caused by lack of mixing did not show an excessive number of significant violations. In general, the results indicated 1) that detection at an upstream site did not influence the probability of subsequent detection downstream, 2) that detection did not influence subsequent survival, and 3) that treatment and reference fish were mixed at subsequent detection sites.

Similarity between survival probability estimates for trap releases and for our primary releases suggested that effects of handling, marking, and release procedures are similar for SMP trap and NMFS/UW purse-seining operations. Standard errors associated with pooled survival estimates for the trap releases are similar to those for our primary releases. However, the trap releases were pooled over 3 to 4 weeks. Over the same period, by purse seining, the NMFSAJW study obtained 12 or 11 survival estimates, each with precision comparable to the single estimate for trap releases. To have a chance of relating survival probabilities with changing conditions throughout a migration season will require multiple survival estimates with high precision.

The survival estimates for hatcheries upstream from Lower Granite Dam, Smolt Monitoring Program traps, and releases from the Port of Wilma indicated that most of the mortality documented between the hatcheries and Lower Granite Dam forebay probably occurred in river sections upstream from Lower Granite Reservoir.

Overall, results indicated that mortality from the head of Lower Granite Reservoir to the tailrace of Lower Granite Dam was less than 10% for hatchery yearling chinook salmon and hatchery steelhead. Because this estimate included mortality associated with dam passage as well as reservoir mortality, it appeared that relatively low mortality occurred in the reservoir. For example, if turbine passage mortality is 15% and 40% of fish pass Lower Granite Dam via turbines, then turbine passage alone can account for 6% overall mortality. Because there is also some mortality associated with spillway and bypass system passage, it appears that little of the 10% overall mortality can be attributed to the reservoir. Similar results indicated that relatively low mortality occurred in the other reservoirs investigated.

The river sections over which survival probabilities were estimated for the primary releases represent about 69% of the distance from the head of Lower Granite Reservoir to the confluence of the Snake and Columbia Rivers (Port of Wilma to Lower Granite Dam tailrace, 49 km; Lower Granite Dam tailrace to Little Goose Dam tailrace, 60 km; and Little Goose Dam tailrace to Lower Monumental Dam tailrace, 46 km). The estimated survival probability from the

Port of Wilma to Lower Monumental Dam tailrace (155 km) was 78% for hatchery chinook salmon and 80% for hatchery steelhead.

Survival estimates from Lower Monumental Dam tailrace to McNary Dam tailrace (two reservoirs and two hydroelectic projects) for hatchery yearling chinook salmon released in Lower Granite Dam tailrace were also high (85%). However, these estimates were derived using the Single-Release Model without post-detection bypass survival estimates at McNary Dam. Post-detection bypass survival was assumed to be 100% at McNary Dam. Nonetheless, these estimates were similar to those for upstream river sections. These estimates extend the distance for which survival estimates are available, downstream an additional 119 km and through two additional dams. Survival from Lower Granite Dam tailrace to McNary Dam tailrace (225 km) was 71% for hatchery yearling chinook salmon.

Combining the estimate from the head of Lower Granite Reservoir to Lower Monumental Dam tailrace with that from Lower Monumental Dam tailrace to McNary Dam tailrace (acknowledging the assumptions required to do so), the estimated survival probability for hatchery yearling chinook salmon from the head of Lower Granite Reservoir to the tailrace of McNary Dam was 67%. This represents 54% of the total length of the hydropower corridor and passageby 5 of 8 dams. This survival estimate does not represent the whole season, but is a first approximation to a seasonal estimate, based on fish passing Lower Granite Dam between 9 April and 13 May.

System survival estimates from this study have been consistently higher than those reported by Raymond (1979) and Sims and Ossiander (1981). From 1970 to 1974, Raymond (1979) estimated an average survival rate of 36% from Little Goose Dam to Ice Harbor Dam.

Our estimate of survival through 3 dams on the Snake River was 76%; more than double Raymond's average and 1.5 times higher than the best survival rate from the 1970s. Raymond's estimates were made using less sophisticated methods and his measurements were made on a river system substantially different from today's (Williams and Matthews, 1995). Management strategies should rely on system survival estimates that are relevant to present passage conditions and under conditions projected for the future. Knowledge of the magnitude, locations, and causes of smolt mortality is essential to develop strategies for optimizing smolt survival.

Estimates of survival probabilities and travel times through downstream reaches were nearly identical for hatchery and wild yearling chinook salmon released into Lower Granite Dam tailrace. This result supports our use of hatchery fish as surrogates for wild fish for conducting survival studies in an effort to reduce handling and mortality of wild stocks.

During the spring of 1995, a voluntary spill program was begun on 14 April at Little Goose, Lower Monumental, and McNary Dams. When spill began at Lower Granite, Dam (3 May), about half of our 12 primary release groups of hatchery yearling chinook had largely passed Lower Granite Dam. The general trend for the 12 primary releases was toward faster migration rates (shorter travel times) as the fish progressed downstream from the Port of Wilma to McNary Dam. This trend was less apparent for the 11 primary releases of hatchery steelhead.

Rondorf and Banach (1995) found that many radio-tagged hatchery yearling chinook salmon and hatchery steelhead traveled quickly from the head of Lower Granite Reservoir to the forebay of Lower Granite Dam, but remained in the forebay area for a considerable amount of time before passing the dam. This could explain the slower migration rates found for PIT-tagged yearling chinook in Lower Granite Reservoir compared to downstream reaches.

Both hatchery chinook salmon and hatchery steelhead increased their rates of migration as the season progressed, especially in the upstream reaches. A combination of increasing flow, spill, water temperature, and smolt development likely contributed to this behavior. Berggren and Filardo (1993) found an increase in migration rate in the Snake and. Columbia Rivers as these variables increased. They found that flow was the most influential variable followed by a smoltification-related variable, which they used as a surrogate for smolt development. Smolt development increases in hatchery yearling chinook salmon after release from the hatchery, and continues to increase as they migrate downstream (Beeman et al. 1991, Muir et al. 1994, Zaugg et al. 1985).

Survival estimates from Lower Granite Dam tailrace to Little Goose Dam tailrace for primary releases and hatchery releases were again the lowest estimates observed of the three river sections investigated in 1995. However, they were higher than in 1994.

Survival estimates in each of the reaches investigated during 1995 were higher for both hatchery yearling chinook sahnon and hatchery steelhead than in previous years. We attribute this increase, in part, to improved migration conditions caused by higher flows, and to a higher proportion of smolts passing via non-turbine routes due to the spill program, which began earlier in 1995. We saw no evidence of increased mortality caused by the spill program in any of the reaches investigated.

In conclusion, we believe that accurate and precise estimates of system survival from an upstream release site in the Snake River Basin to the tailraces of Lower Granite, Little Goose, or Lower Monumental Dams are now possible using the SR, MSR, and PR methodologies with the PIT-tag diversion systems in place and with sufficient release numbers. These methodologies should also be used to extend survival estimates over a larger stretch of river once PIT-tag detectors are installed at additional downstream dams. This will permit exploration of the relationships among smolt survival, smolt travel time, smolt quality, and environmental conditions encountered during migration. Moreover, the data collected in the first 3 years of this study provide valuable baseline information for evaluation of future management strategies.

RECOMMENDATIONS

Successful validation of field and statistical methodologies in 1995 formed the basis for the following recommendations for 1996 and future years:

1) The SR (MSR when appropriate) and PR methodologies should be adopted for survival estimation. Future protocols should be designed to evaluate the effects of seasonal and environmental variation, expanded study areas, and additional sahnonid stocks.

2) No additional post-detection bypass releases at Lower Granite, Little Goose, and Lower Monumental Dams are warranted for yearling chinook salmon and steelhead under flow, water temperature, and spill conditions similar to those we observed in 1995 and in earlier years.

3) Hatcheries should be provided with minimum release-size requirements for their PIT-tag studies so that survival estimates from hatcheries to detection sites at dams can be made with known precision.

4) If plans for a Lower Granite Reservoir drawdown continue, the SR and PR methodologies should be applied to collect survival data during both the baseline data-collection period and the drawdown test.

5) Future survival studies should be coordinated with other inriver projects to maximize the data-collection effort and minimize study effects on salmonid resources.

6) Improved statistical precision should be accomplished by maximizing the return of PIT-tagged juveniles to the river through increased efficiency of detectors and diverters.

7) Additional releases of PIT-tagged yearling chinook salmon should be made in the free-flowing Snake River between the hatcheries and the head of Lower Granite Reservoir to help determine where mortality occurs.

8) The number of detection facilities in the Columbia River Basin should be increased to improve survival investigations. This would include installation of detectors and diversion systems at John Day, The Dalles, Bonneville, and Priest Rapids Dams. The development of flat plate detector technology in bypass systems would greatly enhance survival estimation capabilities.

ACKNOWLEDGMENTS

We express our appreciation to all who assisted with this research. We particularly thank Charles Krahenbuhl, Project Manager of Lower Granite and Little Goose Dams, and Teri Barila, Dan Kenney, and Rebecca Kalamasz of the Walla Walla District, U.S. Army Corps of Engineers (COE) who had the diicult task of coordinating reservoir/project operations and research needs at the dams. The COE also provided PIT tags for the study. At Lower Granite Dam, Tim Wik (COE) and Pete Verhgy (Washington Department of Fisheries), at Little Goose Dam, Rex Baxter (COE) and Todd Hilson (Oregon Department of Fish and Wildlife), and at Lower Monumental Dam, Bill Spurgeon (COE), Paul Wagner, and Monty Price (Washington Department of Fish and Wildlife) provided valuable assistance: Alec Maule (National Biological Service) conducted physiological assays. Carter Stein and staff of the Pacific States Marine Fisheries Commission provided valuable assistance in data acquisition.

Coastal Zone and Estuarine Studies Division staff from all major research stations participated in the study. Scott Davidson, Ron Marr, and staff at the Pasco Field Station coordinated much of the planning and operational elements and minimized potential logistical problems. Jerrel Harmon, Doug Marsh, and staff at Lower Granite Dam aided with the tagging effort at Lower Granite Dam. Earl Dawley, Dennis Enright, and David Miller, along with two purse-seine vessels, represented the Point Adams Field Station and provided valuable expertise with all purse-seining operations.

Peter Westhagen and Judy Cress of the Center for Quantitative Science at the University of Washington School of Fisheries provided critical data management and computer programming support.

Support for this research came from the region's electrical ratepayers through the Bonneville Power Administration, the U.S. Army Corps of Engineers, and the National Marine Fisheries Service.

REFERENCES

Achord, S., J. R. Harmon, D. M. Marsh, B. P. Sandford, K. W. McIntyre, K. L. Thomas, N. N. Paasch, and G. M. Matthews. 1992. Evaluation of transportation ofjuvenile salmonids and related research on the Columbia and Snake Rivers, 1991. Report to U. S. Army Corps of Engineers, Contract DAW68-84-H0034, 57 p. (Available from Northwest Fisheries Science Center, 2725 Montlake Blvd. E., Seattle, WA 98112-2097.)

Beeman, J. W., D. W. Rondorf, J. C. Fowler, P. V. Haner, S. T. Sauter, D. A. Venditti. 1991. Assessment of smolt condition for travel time analysis. Annual Report 1990 to Bonneville Power Administration, Contract DE-AI79-87-BP35245, 71 p. (Available from Bonneville Power Administration, Div. of Fish and Wildlife-PJ. P.O. Box 3621, Portland, OR 97208.)

Berggren, T. J. and M. J. Filardo. 1993. Analysis of variables influencing the migration of juvenile sahnonids in the Columbia River Basin. N. Am. J. Fish. Manage. 13:48-63.

Burnham, K. P., D. R. Anderson, G. C. White, C. Brownie, and K. H. Pollock. 1987. Design and analysis methods for fish survival experiments based on release-recapture. Am. Fish. Soc. Monograph 5: l-437.

Cormack, R. M. 1964. Estimates of survival from the sightings of marked animals. Biometrika 5 1:429-438.

Dauble, D. D., J. Skalski, A. Hoffmann, and A. E. Giorgi. 1993. Evaluation and application of statistical methods for estimating smolt survival. Report to the Bonneville Power Administration, Contract DE-AC06-76RL0 1830, 97 p. (Available from Bonneville Power Administration - PJ, P.O. Box 3621, Portland, OR 97208.)

Hunter, J. E., F. L. Schmidt, and G. B. Jackson. 1982. Meta-analysis: cumulating research findings across studies Sage Publishing, Beverly Hills, CA, 176 p.

Iwamoto, R. N., W. D. Muir, B. P. Sandford, K. W. McIntyre, D. A. Frost, J. G. Williams, S. G. Smith, and J. R. Skalski. 1994. Survival estimates for the passage ofjuvenile chinook salmon through Snake River dams and reservoirs, 1993. Annual report to Bonneville Power Administration, Portland, OR Contract DE-AI79-93BP10891, Project 93-29, 126 p. plus Appendixes. (Available from Northwest Fisheries Science Center, 2725 Montlake Blvd. E., . Seattle, WA 98 112-2097.)

Jolly, G. M. 1965. Explicit estimates from capture-recapture data with both death and immigration--stochastic model. Biometrika 52:225-247.

Muir, W. D., A. E. Giorgi, and T. C. Coley. 1994. Behavioral and physiological changes in yearling chinook salmon during hatchery residence and downstream migration. Aquaculture 127:69-82.

Muir, W. D., S. G. Smith, R. N. Iwamoto, D. J. Kamikawa, K. W. McIntyre, E. E. Hockersmith, B. P. Sandford, P. A. Ocker, T. E. Ruehle, J. G. Williams, and J. R. Skalski. 1995. Survival estimates for the passage of juvenile salmonids through Snake River dams and reservoirs, 1994. Annual report to Bonneville Power Administration, Portland, OR, Contract DE-AI79-93BP10891, Project 93-29, and U.S. Army Corps of Engineers, Walla Walla, WA, Project E86940 119, 187 p. (Available from Northwest Fisheries Science Center, 2725 Montlake Blvd. E., Seattle, WA 98112-2097.)

Normandeau Associates, Inc., J. R. Skalski, and Mid Columbia Consulting, Inc. 1995. Turbine passage survival of juvenile chinook salmon (*Oncorhynchus tshawytscha*) at Lower Granite Dam, Snake River, Washington. Report to U.S. Army Corps of Engineers, Walla Walla, WA.

Prentice, E. F., T. A. Flagg, and C. S. McCutcheon. 1990a. Feasibility of using implantable passive integrated transponder (PIT) tags in salmonids. Am. Fish. Soc. Symposium 7:317-322.

Prentice, E. F., T. A. Flagg, C. S. McCutcheon, and D. F. Brastow. 1990b. PIT-tag monitoring systems for hydroelectric dams and fish hatcheries. Am. Fish. Soc. Symposium 7:323-334.

Prentice, E. F., T. A. Flagg, C. S. McCutcheon, D. F. Brastow, and D. C. Cross. 1990c. Equipment, methods, and an automated data-entry station for PIT tagging. Am. Fish. Soc. Symposium 7:335-340.

Raymond, H. L. 1979. Effects of dams and impoundments on migrations ofjuvenile chinook salmon and steelhead from the Snake River, 1966 to 1975. Trans. Am. Fish. Soc. 108(6):505-529.

Rondorf, D. W. and M. J. Banach. 1995. Migrational characteristics ofjuvenile spring chinook salmon and steelhead in Lower Granite Reservoir and tributaries. Snake River. Report to the U.S. Army Corps of Engineers, Contract E8693015 1, Walla Walla, WA.

Rottiers, D. V. 199 1. Towable cage for studies of smoltification in Atlantic salmon. Prog. Fish-Cult. 53:124-127.

Seber, G. A. F. 1965. A note on the multiple recapture census. Biometrika 52:249-259.

Sims, C., and F. Ossiander. 1981. Migrations ofjuvenile chinook salmon and steelhead in the Snake River, from 1973 to 1979, a research summary. Report to the U.S. Army Corps of Engineers, Contract DACW68-78-0038, 3 1 p. plus Appendix. (Available from Northwest Fisheries Science Center, 2725 Montlake Boulevard E., Seattle, WA 98112-2097.)

Skalski, J. R., A. Hoffmann, and S. G. Smith. 1993. Testing the significance of individual and cohort-level covariates in animal survival studies. In: J. D. Lebreton and P. M. North (editors.), The use of marked individuals in the study of bird population dynamics: Models, methods, and software, p. l-17, Birkhauser Verlag, Basel, 273 p.

Smith, S. G., J. R. Skalski, W. Schlechte, A Hoffmann, and V. Cassen. 1994. Statistical Survival Analysis of Fish and Wildlife Tagging Studies. SURPH. 1 Manual. (Available from Center for Quantitative Science, HR-20, University of Washington, Seattle, WA 98 195 .)

Sokal, R. R., and F. J. Rohlf. 1981. Biometry. Second edition. W. H. Freeman New York, 832 p.

Williams, J.G., and G. M. Matthews. 1995. A review of flow survival relationships for spring and summer chinook salmon, *Oncorhynchus tshawytscha*, from the Snake River Basin. Fish. Bull. 93:732-740.

Zaugg, W. S., E. F. Prentice, and F. W. Waknitz. 1985. Importance of river migration to the development of seawater tolerance in Columbia River anadromous salmonids. Aquaculture 41:33-47.

APPENDIX A -- TESTS OF MODEL ASSUMPTIONS

Methods

For the SR Model the critical assumptions are:

A1) A fish's detection at a PIT-tag detection site does not affect its probability of subsequent detection at downstream sites.

A2) A fish's detection at a PIT-tag detection site does not affect its probability of subsequent survival through downstream river reaches.

A3) Detected fish suffer no significant post-detection mortality in the bypass system before remixing with non-detected fish.

If Assumption A3 failed, the MSR Model was used in place of the SR Model to analyze the primary releases. Each release under the MSR Model is assumed to satisfy Assumptions A1 and A2. There is one additional critical assumption for the post-detection bypass paired releases:

A4) Treatment release groups and their corresponding reference groups mix evenly and travel together downstream from the source of mortality under investigation.

The PR Model shares the assumptions of the MSR Model.

Taken together, tests of Assumptions A1 and A2 can be thought of as general tests of the "goodness of fit" of the SR Model to the data. Burnham et al. (1987) gave a series of goodness-of-fit tests to be used for the SR Model (TESTs 2 and 3, Burnham et al. 1987, p. 71-77) and noted that factors that lead to rejection of the tests include heterogeneity of parameters across individuals, failure of the assumption of independent fish fates, and behavioral response to capture and subsequent release (i.e., behavioral changes after passage through a juvenile bypass facility).

The same goodness-of-fit tests (Tables Al and A2) were conducted in 1995 as in 1994. Details of the tests were presented by Muir et al., 1995.

Experiment-wise Error Rate

Each series of contingency table tests was considered to be a separate and independent experiment (Table A3). Significance levels for individual tests (α_T) were selected to control the experiment-wise Type I error rate (α_{EX}) (Table A4). For a given experiment-wise Type I error rate, the test-wise significance level was computed as follows (Sokal and Rohlf 1981):

$$\alpha_T = 1-(1-\alpha_{EX})^{\frac{1}{k}}$$

where k was the number of tests in the experiment. For example, for a series of twelve tests, setting the experiment-wise Type I error rate to $\alpha_{EX} = 0.05$ required a test-wise significance level of $\alpha_T = 0.0043$.

Results

Assumptions A1 and A2--A fish's detection at a PIT-tag detection site does not affect its probability of subsequent survival in downstream reaches or of subsequent detection at downstream sites.

For most primary release groups of hatchery chinook salmon, there were no significant differences in Little Goose Dam passage distributions between fish detected and not detected at Lower Granite Dam (Table A5). However, for almost all release groups, passage distributions at

Appendix Table Al. Tests of goodness of fit to the Single-Release Model that can be calculated for releases above Lower Granite Dam (notation of Burnham et al. 1987). Abbreviations: LGR-Lower Granite Dam; LGO-Little Goose Dam; LMO-Lower Monumental Dam; MCN-McNary Dam.

Test	Tests homogeneity of	Degrees of freedom
TEST 2.C2	First detection location below LGR for two subgroups of a primary release group defined by capture history at LGR	2
TEST 2.C3	First detection location below LGO for two subgroups of a primary release group defined by capture history at LGO.	1
TEST 2	Sum of TEST 2.C2 and TEST 2.C3.	3
TEST 3 .SR3	"Seen again versus not seen again" for two subgroups of a primary release group detected at LGO, defined by capture history at LGR.	1
TEST 3.Sm3	"Seen next at LMO versus seen next at MCN" for two subgroups of a primary release group detected at LGO, defined by capture history at LGR.	1
TEST 3.SR4	"Seen again versus not seen again" for two subgroups of a primary release group detected at LMO, defined by "seen at LGR or LGO "versus not seen at LGR or LGO."	1
TEST 3	Sum of TEST 3.SR3, TEST 3.Sm3, and TEST 3.SR4	3
Overall	Sum of TEST 2 and TEST 3.	6

Appendix Table A2. Tests of goodness of fit to the Single-Release Model that can be calculated for releases at Lower Granite Dam (notation of Burnham et al. 1987). Abbreviations: LGR-Lower Granite Dam; LGO-Little Goose Dam; LMO-Lower Monumental Dam; MCN-McNary Dam.

Test	Tests homogeneity of	Degrees of freedom
TEST 2.C2	First detection location below LGO for two subgroups of a LGR releas group defined by capture history at LGO.	1
TEST 3 .SR3	"Seen again versus not seen again" for two subgroups of a LGR release group detected at LMO, defined by capture history at LGO.	1
Overall	Sum of TEST 2.C2 and TEST 3.SR3.	2

Appendix Table A3. Number of contingency table tests in each series used to test assumptions of Single-Release and Paired-Release Models. Abbreviations: LGO-Little Goose Dam; LMO-Lower Monumental Dam; MCN-McNary Dam.

	Tests of homogeneity of passage distributions			Goodness-of-fit tests				
Releases	LGO	LMO	MCN	2.C2	2.C3	3.SR3	3.Sm3	3.SR4
Primary releases of hatchery yearling chinook salmon	12	12	12	12	12	12	12	12
Primary releases of hatchery steelhead	11	11	11	11	11	11	11	11
Post-detection bypass/reference releases of hatchery yearling chinook salmon from Lower Granite Dam	4	4	4	4	---	4	---	---
Turbine/reference releases of hatchery yearling chinook salmon from Lower Granite Dam	4	4	4	4	---	4	---	---
Post-detection bypass/reference releases of hatchery steelhead from Lower Granite Dam	5	5	5	5	---	5	---	---
Post-detection bypass/reference releases of hatchery yearling chinook salmon from Little Goose Dam	---	5	5	---	---	---	---	---
Post-detection bypass/reference releases of hatchery yearling chinook salmon from Lower Monumental Dam	---	---	5	---	---	---	M-	---
Post-detection bypass/reference releases of hatchery steelhead from Lower Monumental Dam	---	---	5	---	m-	-e-	---	---

Appendix Table A4. Test-wise significance (α_T) levels corresponding to experiment-wise Type I error rates (α_{EX}) of 0.10, 0.05, 0.01.

Number of tests	Experiment-wise significance levels (α_{EX})		
	0.10	0.05	0.01
1	0.1000	0.0500	0.0100
2	0.0513	0.0253	0.0050
3	0.0345	0.0170	0.0033
4	0.0260	0.0127	0.0025
5	0.0209	0.0102	0.0020
6	0.0174	0.0085	0.0017
7	0.0149	0.0073	0.0014
8	0.0131	0.0064	0.0013
9	0.0116	0.0057	0.0011
10	0.0105	0.0051	0.0010
11	0.0095	0.0047	0.0009
12	0.0087	0.0043	0.0008

Appendix Table A5. Tests of homogeneity of Little Goose Dam passage distributions for subgroups of primary releases of hatchery yearling chinook salmon defined by capture history at Lower Granite Dams. P values calculated using Monte Carlo approximation of the exact method.

Release	χ^2	Degrees of freedom	P value*
R_{P1}	21.71	27	0.821
R_{P2}	30.13	25	0.176
R_{P3}	36.26	32	0.276
R_{P4}	28.58	24	0.194
R_{P5}	27.77	25	0.293
R_{P6}	25.95	26	0.485
R_{P7}	41.74	26	0.006
R_{P8}	20.91	25	0.764
R_{P9}	33.38	28	0.177
R_{P10}	20.85	20	0.409
R_{P11}	17.34	19	0.609
R_{P12}	24.78	13	0.006

* To control experiment-wise Type I error rate (e.g., $\alpha_{EX} = 0.05$), test-wise P values are compared to adjusted significance levels for 12 tests (e.g., $\alpha_T = 0.0043$) (see Table 9).

Lower Monumental Dam differed substantially among subgroups (Table A6), mainly due to faster passage through Little Goose Dam for nondetected than for detected fish. Median travel times between Lower Granite and Lower Monumental Dams were as much as 1.6 days longer for fish detected at Little Goose Dam than for fish not detected there.

Finally, passage distributions at McNary Dam for subgroups of the primary releases did not differ significantly (Table A7). This suggested that hatchery chinook salmon that were delayed in bypass systems at Lower Granite and Little Goose Dams caught up with their nondetected counterparts by the time they reached McNary Dam.

Despite frequent differences in passage distributions for detected and nondetected fish, there was little lack of fit of the SR Model to the primary releases of hatchery chinook salmon (Table A8). Only R_{P5} had a significant overall lack of fit. The most significant for R_{P5} was TEST 3.Sm3, i.e. significant differences in Lower Monumental and McNary Dam detections depending on detection at Lower Granite Dam. Fish from R_{P5} were passing Lower Monumental Dam around the time spill volumes increased in early May. The significant TEST 3.Sm3 for this group might be explained by fish passing via spill at Lower Granite Dam arriving at Lower Monumental Dam largely before spill volumes increased, while those passing via bypass system were delayed and arrived under high spill conditions.

Primary releases of hatchery steelhead also showed evidence of differences in travel times between detected and nondetected fish (Tables A9, A10, and Al 1). Significant differences in passage distributions occurred throughout the season for subgroups at Lower Monumental Dam. Differences also occurred at Little Goose Dam late in the season, after spill had begun at Lower Granite Dam. Differences in median travel times for detected and nondetected hatchery steelhead

Appendix Table A6. Tests of homogeneity of Lower Monumental Dam passage distributions for subgroups of primary releases of hatchery yearling chinook salmon defined by capture history at Lower Granite and Little Goose Darns. P-values calculated using Monte Carlo approximation of the exact method.

Release	χ^2	Degrees of freedom	P value*
R_{P1}	106.0	84	0.030
R_{P2}	77.52	63	0.082
R_{P3}	118.1	96	0.048
R_{P4}	97.11	78	0.048
R_{P5}	80.52	66	0.086
R_{P6}	123.6	81	<0.001
R_{P7}	100.3	78	0.024
R_{P8}	91.57	69	0.021
R_{P9}	100.4	84	0.084
.R_{P10}	95.41	66	0.008
R_{P11}	45.07	57	0.885
R_{P12}	48.58	45	0.350

* To control experiment-wise Type I error rate (e.g., $\alpha_{EX} = 0.05$), test-wise P values are compared to adjusted significance levels for 12 tests (e.g.. $\alpha_T = 0.0043$) (see Table 9).

Appendix Table A7. Tests of homogeneity of McNary Dam passage distributions for subgroups of primary releases of hatchery yearling chinook salmon defined by capture history at Lower Granite, Little Goose, and Lower Monumental Dams. P values calculated using Monte Carlo approximation of the exact method.

Release	χ^2	Degrees of freedom	P value*
R_{P1}	198.0	182	0.207
R_{P2}	181.2	161	0.131
R_{P3}	203.7	203	0.480
R_{P4}	186.2	147	0.017
R_{P5}	175.0	161	0.202
R_{P6}	182.0	161	0.096
R_{P7}	188.8	161	0.041
R_{P8}	141.6	147	0.625
R_{P9}	169.1	168	0.470
R_{P10}	164.4	168	0.569
R_{P11}	121.5	102	0.127
R_{P12}	48.03	45	0.651

* To control experiment-wise Type I error rate (e.g., $\alpha_{EX} = 0.05$), test-wise P values are compared to adjusted significance levels for 12 tests (e.g., $\alpha_T = 0.0043$) (see Table 9).

Appendix Table A8. Results of tests of goodness of fit to the Single-Release Model for primary releases of hatchery yearling chinook salmon from the Port of Wilma (TEST 2 and TEST 3 of Burnham et al. 1987).

	Overall		TEST 2		TEST 2.C2		TEST 2.C3	
Release	χ^2	P value’	χ^2	P value*	χ^2	P value*	χ^2	P value*
R_{P1}	3.826	0.700	2.177	0.536	1.446	0.485	0.731	0.393
R_{P2}	2.986	0.811	1.819	0.611	0.905	0.636	0.914	0.339
R_{P3}	10,061	0.122	3.564	0.313	0.975	0.614	2.589	0.108
R_{P4}	10.296	0.113	1.198	0.753	0.198	0.906	1.000	0.317
R_{P5}	13.770	0.032	6.823	0.078	5.772	0.056	1.051	0.305
R_{P6}	5.060	0.536	1.582	0.663	1.332	0.514	0.250	0.617
R_{P7}	8.844	0.183	1.438	0.697	0.885	0.642	0.553	0.457
R_{P8}	4.609	0.595	3.444	0.328	2.321	0.313	1.123	0.289
R_{P9}	5.783	0.448	3.565	0.312	0.275	0.872	3.290	0.070
R_{P10}	9.995	0.125	6.476	0.091	5.425	0.066	1.051	0.305
R_{P11}	6.698	0.350	3.892	0.273	0.198	0.906	3.694’	0.055
R_{P12}	4.713	0.581	2.449	0.485	1.735	0.420	0.714	0.398

* To control experiment-wise Type 1 error rate (e.g., $\alpha_{EX} = 0.05$), test-wise P values are compared to adjusted significance levels for 12 tests (e.g., $\alpha_T = 0.0043$) (see Table 9).

Appendix Table A8. Continued.

Release	TEST 3		TEST 3.SR3		TEST 3.Sm3		TEST 3.SR4	
	χ^2	P value’	χ^2	P value*	χ^2	P value*	χ^2	P value*
R_{P1}	1.649	0.648	0.781	0.377	0.184	0.668	0.684	0.408
R_{P2}	1.167	0.761	0.469	0.493	0.090	0.764	0.608	0.436
R_{P3}	6.497	0.090	0.007	0.933	2.742	0.098	3.748	0.053
R_{P4}	9.098	0.028	0.858	0.354	2.517	0.113	5.723	0.017
R_{P5}	6.947	0.074	0.016	0.899	6.891	0.009	0,040	0.841
R_{P6}	3.478	0,324	3.018	0.082	0.110	0.740	0.350	0.554
R_{P7}	7.406	0.060	2.010	0.156	0.443	0.506	4.953	0.026
R_{P8}	1.165	0.761	0.010	0.920	0.031	0.860	1.124	0.289
R_{P9}	2.218	0.528	1.093	0.296	0.035	0.852	1,090	0.296
R_{P10}	3.519	0.318	1.661	0.197	0.129	0.719	1.729	0.189
R_{P11}	2.806	0.423	0.470	0.493	2.072	0.150	0.264	0.607
R_{P12}	2.264	0.519	1.740	0.187	0.288	0.592	0.236	0.627

* To control experiment-wise Type I error rate (e.g., $\alpha_{EX} = 0.05$), test-wise P values are compared to adjusted significance levels for 12 tests (e.g., $\alpha_T = 0.0043$) (See Table 9).

Appendix Table A9. Tests of homogeneity of Little Goose Dam passage distributions for subgroups of primary releases of hatchery steelhead defined by capture history at Lower Granite Dam. P values calculated Monte Carlo approximation-of the exact method.

Release	χ^2	Degrees of freedom	P value*
R_{P1}	22.95	22	0.414
R_{P2}	28.70	27	0.369
R_{P3}	29.56	23	0.194
R_{P4}	27.26	24	0.3 13
R_{P5}	24.42	22	0.326
R_{P6}	38.93	20	0.001
R_{P7}	31.90	21	0.025
R_{P8}	38.82	18	<0.001
R_{P9}	58.42	24	co.00 1
R_{P10}	49.43 .	23	<0.001
R_{P11}	13.66	10	0.130

* To control experiment-wise Type I error rate (e.g., $\alpha_{EX} = 0.05$), test-wise P values are compared to adjusted significance levels for 11 tests (e.g., $\alpha_T = 0.0047$) (see Table 9).

Appendix Table Al 0. Tests of homogeneity of Lower Monumental Dam passage distributions for subgroups of primary releases of hatchery steelhead defined by capture history at Lower Granite and Little Goose Dams. P values calculated using Monte Carlo approximation of the exact method.

Release	χ^2	Degrees of freedom	P value*
R_{P1}	109.2	72	0.010
R_{P2}	96.93	72	0.025
R_{P3}	91.62	75	0.125
R_{P4}	108.9	78	0.039
R_{P5}	134.9	81	<0.001
R_{P6}	88.02	72	0.075
R_{P7}	97.46	69	0.008
R_{P8}	113.8	72	<0.001
R_{P9}	130.3	84	<0.001
R_{P10}	116.0	93	0.026
R_{P11}	44.34	45	0.570

* To control experiment-wise Type I error rate (e.g., $\alpha_{EX} = 0.05$), test-wise P values are compared to adjusted significance levels for 11 tests (e.g., $\alpha_T = 0.0047$) (see Table 9).

Appendix Table Al 1. Tests of homogeneity of McNary Dam passage distributions for subgroups of primary releases of hatchery steelhead defined by capture history at Lower Granite, Little Goose, and Lower Monumental Dams. P values calculated using Monte Carlo approximation of the exact method.

Release	χ^2	Degrees of freedom	P value*
R_{P1}	214.5	154	0.009
R_{P2}	195.2	161	0.099
R_{P3}	165.2	133	0.080
R_{P4}	158.0	147	0.325
R_{P5}	146.5	140	0.363
R_{P6}	138.8	126	0.180
R_{P7}	138.8	140	0.522
R_{P8}	138.5	119	0.075
R_{P9}	120.6	119	0.456
R_{P10}	181.6	140	0.026
R_{P11}	46.0	42	0.507

* To control experiment-wise Type I error rate (e.g., $\alpha_{EX} = 0.05$), test-wise P values are compared to adjusted significance levels for 11 tests (e.g., $\alpha_T = 0.0047$) (see Table 9).

were greater than 2 days in some cases. There were significant differences among passage distributions at McNary Dam for subgroups of several hatchery steelhead releases.

Several primary releases of hatchery steelhead had significant or nearly significant lack of fit (Table A12) to the SR Model. Releases in the later part of the season were particularly affected by lack of fit.

For post-detection releases of hatchery chinook salmon from Lower Granite Dam, only the first treatment release (R_{B11}) had significant lack of fit to the SR Model (Table A13). For this release, detection at Little Goose Dam influenced the next detection site downstream (TEST 2.C2)

There was no significant lack of fit to the SR Model for post-detection releases of hatchery steelhead (Table A14) or turbine releases of hatchery chinook salmon (Table Al 5) at Lower Granite Dam.

Assumption A3--Detected fish suffer no significant post-detection bypass mortality before remixing with non-detected fish.

At Lower Granite Dam, estimates of post-detection survival for hatchery yearling chinook salmon ranged from 0.871 to 1.060 (Table A16a), with a weighted average of 0.976 (se. 0.036) for the four estimates. For hatchery steelhead, the weighted average of five survival probability estimates was 0.983 (s.e. 0.019) (Table A17a).

At Little Goose Dam, estimates of post-detection survival for hatchery steelhead ranged from 0.929 to 1.102 (Table A17b), with a weighted average of 0.979 (s.e. 0.03 1).

At Lower Monumental Dam, the five post-detection survival estimates for hatchery yearling chinook salmon ranged from 0.883 to 1.100, with a weighted average of 0.954 (s.e. 0.034)

Appendix Table A12. Results of tests of goodness of tit to the Single-Release Model for primary releases of hatchery steelhead from th Port of Wilma (TEST 2 and TEST 3 of **Burnham** et al. 1987).

	Overall		TEST 2		TEST 2.C2		TEST 2.C3	
Release	χ^2	P value'	χ^2	P value*	χ^2	P value*	χ^2	P value*
R_{P1}	5.954	0.428	5.569	0.135	1.384	0.501	4.185	0.041
R_{P2}	5.577	0.472	3.995	0.262	3.974	0.137	0.021	0.885
R_{P3}	7.277	0.296	5.389	0.145	5.361	0.069	0.028	0.867
R_{P4}	2.836	0.829	0.141	0.986	0.123	0.940	0.018	0.893
R_{P5}	6.782	0.341	6.394	0.094	1.651	0.438	4.743	0.029
R_{P6}	16.055	0.013	12.157	0.007	10.893	0.004	1.264	0.261
R_{P7}	20.739	0.002	7.019	0.071	3.928	0.140	3.091	0.079
R_{P8}	6.972	0.323	3.113	0.375	2.807	0.246	0.306	0.580
R_{P9}	3.520	0.741	1.180	0.758	1.166	0.558	0.014	0.906
R_{P10}	14.665	0.023	10.697	0.013	6.174	0.046	4.523	0.033
R_{P11}	7.187	0.304	3.600	0.308	3.439	0.179	0.161	0.688

* To control experiment-wise Type I error rate (e.g., $\alpha_{EX} = 0.05$), test-wise P values are compared to adjusted significance levels for 11 tests (e.g., $\alpha_T = 0.0047$) (see Table 9).

Appendix Table A 12. Continued.

Release	TEST 3		TEST 3.SR3		TEST 3.Sm3		TEST 3.SR4	
	χ^2	P value*	χ^2	P value*	χ^2	P value*	χ^2	P value*
R_{P1}	0.385	0.943	0.100	0.752	0.236	0.627	0.049	0.825
R_{P2}	1.582	0.663	0.984	0.321	0.001	0.975	0.597	0.440
R_{P3}	1.888	0.596	0.314	0.575	0.394	0.530	1.180	0.277
R_{P4}	2.695	0.441	0.971	0.324	0.255	0.614	1.469	0.226
R_{P5}	0.388	0.943	0.084	0.772	0.158	0.691	0.146	0.702
R_{P6}	3.898	0.273	3.674	0.055	0.221	0.638	0.003	0.956
R_{P7}	13.720	0.003	0.145	0.703	0.032	0.858	13.543	0.000
R_{P8}	3.859	0.277	2.111	0.146	1.657	0.198	0.091	0.763
R_{P9}	2.340	0.505	1.826	0.177	0.368	0.544	0.146	0.702
R_{P10}	3.968	0.265	1.521	0.217	0.079	0.779	2.368	0.124
R_{P11}	3.587	0.310	3.495	0.062	0.091	0.763	0.001	0.975

* To control experiment-wise Type I error rate (e.g., α_{EX} = 0.05), test-wise P values are compared to adjusted significance levels for 11 tests (e.g., α_T = 0.0047) (See Table 9).

Appendix Table A13. Results of tests of goodness of fit to the Single-Release Model for post-detection bypass treatment and reference releases of hatchery yearling chinook salmon from Lower Granite Dam (TEST 2 and TEST 3 of Burnham et al. 1987).

Release	Overall		TEST 2.C2		TEST 3.SR3	
	χ^2	P value*	χ^2	P value*	χ^2	P value*
R_{B11}	13.433	0.001	11.249	0.001	2.184	0.139
C_{B11}	0.202	0.904	0.202	0.653	0.000	1.000
R_{B12}	0.415	0.813	0.288	0.592	0.127	0.722
C_{B12}	5.781	0.056	3.868	0.049	1.913	0.167
R_{B13}	0.221	0.895	0.202	0.653	0.019	0.890
C_{B13}	1.734	0.420	0.404	0.525	1.330	0.249
R_{B14}	7.949	0.019	3.121	0.077	4.828	0.028
C_{B14}	5.105	0.078	3.424	0.064	1.681	0.195

* To control experiment-wise Type I error rate (e.g., $\alpha_{EX} = 0.05$), test-wise P values for bypass releases are compared to adjusted significance levels for four tests (e.g., $\alpha_T = 0.0127$) (see Table 9).

Appendix Table A14. Results of tests of goodness of fit to the Single-Release Model for post-detection bypass treatment and reference releases of hatchery steelhead from Lower Granite Dam (TEST 2 and TEST 3 of Burnham et al. 1987.

Release	Overall		TEST 2.C2		TEST 3.SR3	
	χ^2	P value*	χ^2	P value*	χ^2	P value*
R_{B11}	0.503	0.778	0.417	0.518	0.086	0.769
C_{B11}	1.609	0.447	0.013	0.909	1.596	0.206
R_{B12}	1.551	0.460	1.493	0.222	0.058	0.810
C_{B12}	2.639	0.267	2.033	0.154	0.606	0.436
R_{B13}	0.150	0.928	0.003	0.956	0.147	0.701
C_{B13}	0.054	0.973	0.035	0.852	0.019	0.890
R_{B14}	2.864	0.239	1.865	0.172	0.999	0.318
C_{B14}	0.106	0.948	0.069	0.793	0.037	0.847
R_{B15}	2.799	0.247	0.934	0.334	1.865	0.172
C_{B15}	2.520	0.284	2.510	0.113	0.010	0.920

* To control experiment-wise Type I error rate (e.g., $\alpha_{EX} = 0.05$), test-wise P values for bypass and forebay releases are compared to adjusted significance levels for five tests (e.g., $\alpha T = 0.0102$) (see Table 9).

Appendix Table A15. Results of tests of goodness of fit to the Single-Release Model for turbine test and reference releases of hatchery yearling chinook salmon from Lower Granite Dam (TEST 2 and TEST 3 of Burnham et al. 1987)

	Overall		TEST 2.C2		TEST 3. SR3	
Release	χ^2	P value*	χ^2	P value*	χ^2	P value*
R_{411}	5.829	0.054	5.496	0.019	0.333	0.564
C_{411}	2.747	0.253	2.708	0.100	0.039	0.843
D_{411}	4.303	0.116	4.301	0.038	0.002	0.964
R_{412}	2.888	0.236	2.099	0.147	0.789	0.374
C_{412}	2.224	0.329	1.114	0.291	1.110	0.292
D_{412}	2.505	0.286	0.033	0.856	2.472	0.116

* To control experiment-wise Type I error rate (e.g., $\alpha_{EX} = 0.05$), test-wise P values for bypass releases are compared to adjusted significance levels for two tests (e.g., $\alpha_T = 0.0253$) (see Table 9).

Appendix Table Al 6. Post-detection bypass survival estimates for hatchery yearling chinook salmon released at Lower Granite and Lower Monumental Dams. Standard errors in parentheses. Abbreviations; LGR-Lower Granite Dam; LGO-Little Goose Dam; LMO-Lower Monumental Dam; MCN-McNary Dam.

a) Lower Granite Dam

Releases	Treatment group survival LGR to LGO tailrace	Reference group survival LGR to LGO tailrace	Post-detection bypass survival (S_{B1})
(R_{B11}, C_{B11})	0.826 (0.056)	0.823 (0.052)	1.004 (0.093)
(R_{B12}, C_{B12})	0.922 (0.082)	0.870 (0.05 1)	1.060 (0.113)
(R_{B13}, C_{B13})	0.891 (0.039)	0.893 (0.036)	0.998 (0.059)
(R_{B14}, C_{B14})	0.819 (0.055)	0.940 (0.061)	0.871 (0.122)
Pooled*			0.976 (0.036)

b) Lower Monumental Dam

Releases	Treatment group proportion detected at MCN (%)	Reference group proportion detected at MCN (%)	Post-detection bypass survival (S_{B3})
(R_{B31}, C_{B31})	27.8	30.6	0.909 (0.070)
(R_{B32}, C_{B32})	35.6	36.7	0.969 (0.065)
(R_{B33}, C_{B33})	25.5	24.1	1.058 (0.092)
(R_{B34}, C_{B34})	24.3	27.5	0.883 (0.075)
(R_{B35}, C_{B35})	11.9	10.8	1.100 (0.155)
Pooled’			0.954 (0.034)

* Pooled estimates are weighted averages of the independent estimates, with weights inversely proportional to the respective estimated variances.

Appendix Table Al 7. Post-detection bypass survival estimates for hatchery steelhead released at Lower Granite, Little Goose, and Lower Monumental Dams. Standard errors in parentheses. Abbreviations: LGR-Lower Granite Dam; LGO-Little Goose Dam; LMO-Lower Monumental Dam; MCN-McNary Dam.

a) Lower Granite Dam

Releases	Treatment group survival LGR to LGO tailrace	Reference group survival LGR to LGO tailrace	Post-detection bypass survival (S_{B1})
(R_{B11}, C_{B11})	0.947 (0.036)	0.918 (0.035)	1.032 (0.056)
(R_{B12}, C_{B12})	0.896 (0.030)	0.916 (0.027)	0.978 (0.044)
(R_{B13}, C_{B13})	0.805 (0.032)	0.893 (0.038)	0.901 (0.052)
(R_{B14}, C_{B14})	0.926 (0.027)	0.93 1 (0.027)	0.995 (0.041)
(R_{B15}, C_{B15})	0.898 (0.027)	0.897 (0.027)	1 .001 (0.043)
Pooled*			0.983 (0.019)

b) Little Goose Dam

Releases	Treatment group survival LGO to LMO tailrace	Reference group survival LGO to LMO tailrace	Post-detection bypass survival (S_{B2})
(R_{B21}, C_{B21})	0.893 (0.043)	0.853 (0.043)	1.047 (0.073)
(R_{B22}, C_{B22})	0.93 1 (0.050)	0.975 (0.03 5)	0.955 (0.062)
(R_{B23}, C_{B23})	0.867 (0.025)	0.933 (0.030)	0.929 (0.040)
(R_{B24}, C_{B24})	0.867 (0.053)	0.787 (0.041)	1.102 (0.088)
(R_{B25}, C_{B25}	1.046 (0.064)	1.005 (0.055)	1.041 (0.085)
Pooled*			0.979 (0.03 1)

* Pooled estimates are weighted averages of the independent estimates, with weights inversely proportional to the respective estimated variances.

Appendix Table A17. Continued.

c) Lower Monumental Dam

Releases	Treatment group proportion detected at MCN (%)	Reference group proportion detected at MCN (%)	Post-detection bypass survival (S_{B3})
(R_{B31}, C_{B31})	21.1	23.2	0.909 (0.085)
(R_{B32}, C_{B32})	22.4	20.9	1.072 (0.103)
(R_{B33}, C_{B33})	20.0	19.3	1.039 (0.106)
(R_{B34}, C_{B34})	15.1	15.9	0.954 (0.115)
(R_{B35}, C_{B35})	12.4	16.8	0.740 (0.091)
Pooled*			0.929 (0.060)

* Pooled estimates are weighted averages of the independent estimates, with weights inversely proportional to the respective estimated variances.

(Table A16b). Survival estimates from the five paired releases of hatchery steelhead averaged 0.929 (s.e. 0.060) (Table A17c).

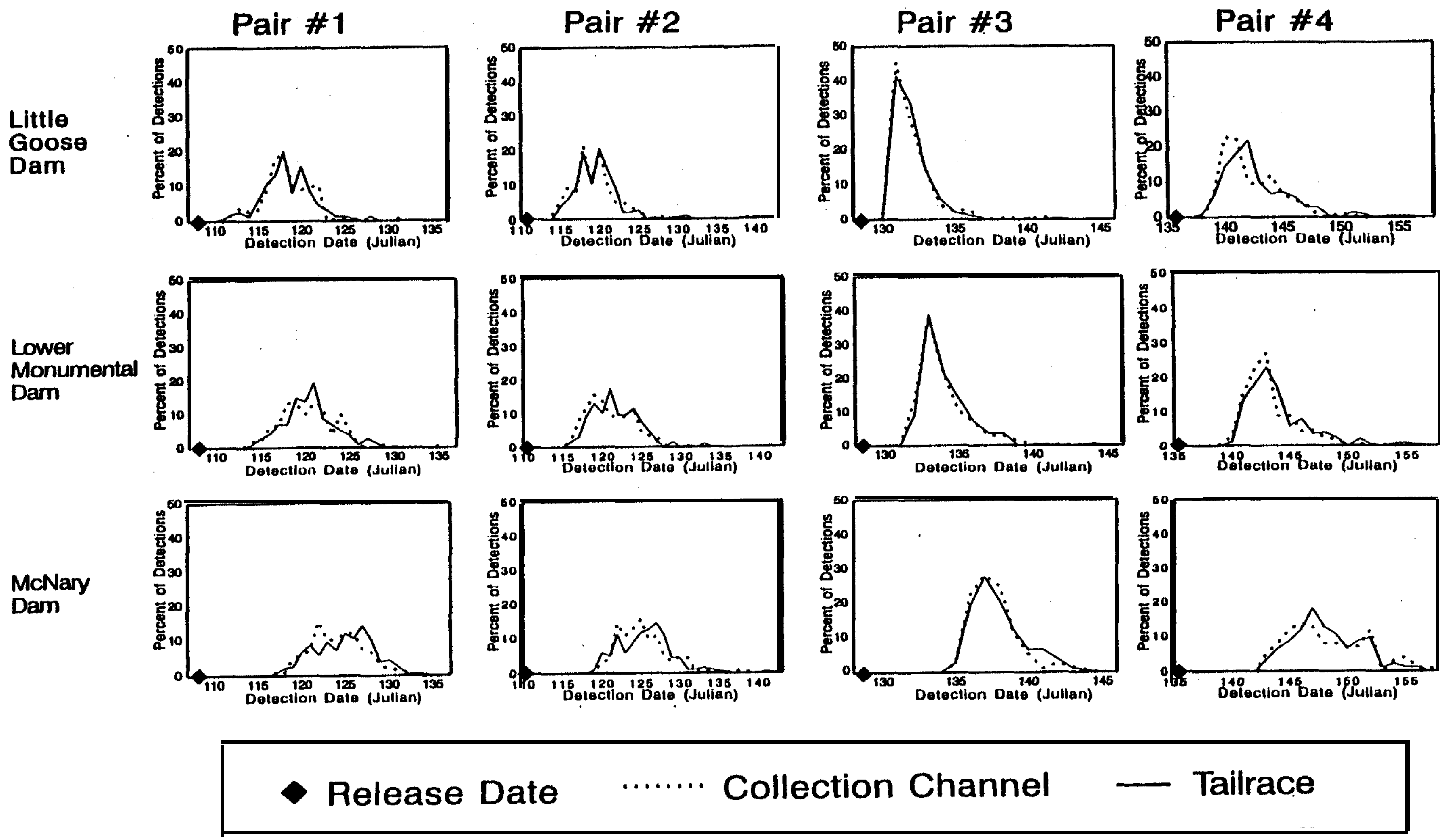
Because1 .0 was included in 95% confidence intervals around the weighted average estimates of post-detection bypass survival of both hatchery yearling chinook salmon and steelhead at all dams, we used the SR Model to estimate survival rates for the primary releases. However, post-detection mortality for both hatchery yearling chinook salmon and hatchery steelbead was nearly significant at the 0.05 level at Lower Monumental Dam.

Assumption A4--Treatment release groups and their corresponding reference groups mix evenly and travel together downstream from the source of mortality under investigation.

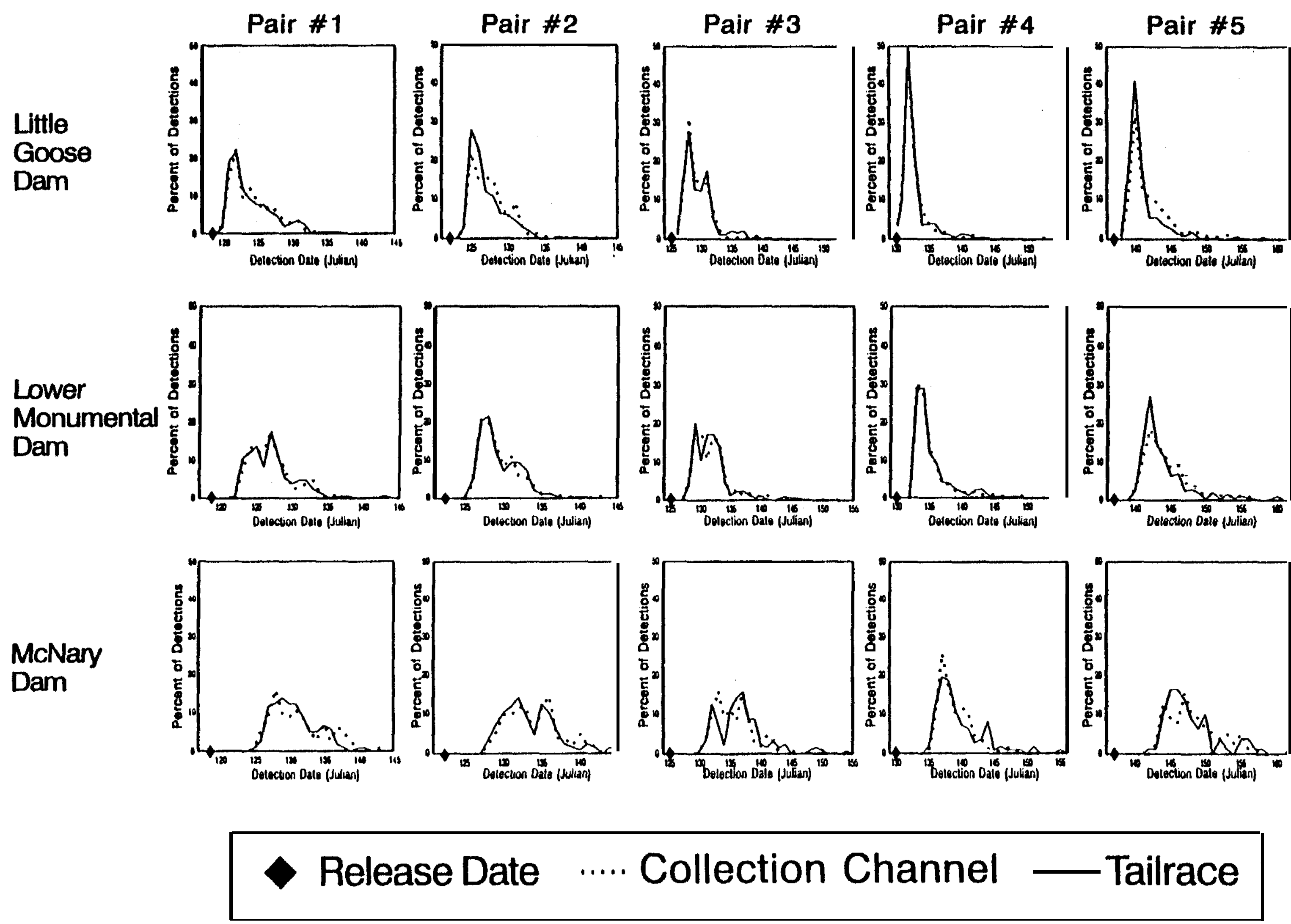
Tests of homogeneity of passage distributions for paired bypass releases of hatchery yearling chinook salmon and steelhead from Lower Granite Dam (Figs. Al and A2; Tables Al 8 and A19) showed some significant differences in passage distributions at downstream dams, particularly at Little Goose Dam for the fifth paired release of hatchery steelhead.

The three simultaneous release groups for turbine evaluation at Lower Granite Dam (treatment, draft tube reference, and bypass reference) mixed poorly, with several highly significant differences in downstream passage (Fig. A3, Table A20a). In both replicate sets, the bypass reference groups arrived downstream sooner than the other two groups. However, passage distributions for the treatment and draft tube references were very similar (Table A20b). For turbine survival estimation, therefore, the bypass reference release was ignored, and the PR Model was applied to the treatment and draft tube reference groups.

Tests of homogeneity of passage distributions for Little Goose Dam paired bypass releases of hatchery steelhead showed some significant differences at Lower Monumental Dam



Appendix Figure A1. Passage distribution at downstream dams for Lower Granite Dam paired bypass releases of hatchery chinook salmon.



Appendix Figure A2. Passage distributions at downstream dams for Lower Granite Dam paired bypass releases of hatchery steelhead.

Appendix Table Al 8. Tests of homogeneity of passage distributions at downstream dams for Lower Granite Dam paired bypass releases of hatchery yearling chinook salmon. P values calculated using Monte Carlo approximation of the exact method.

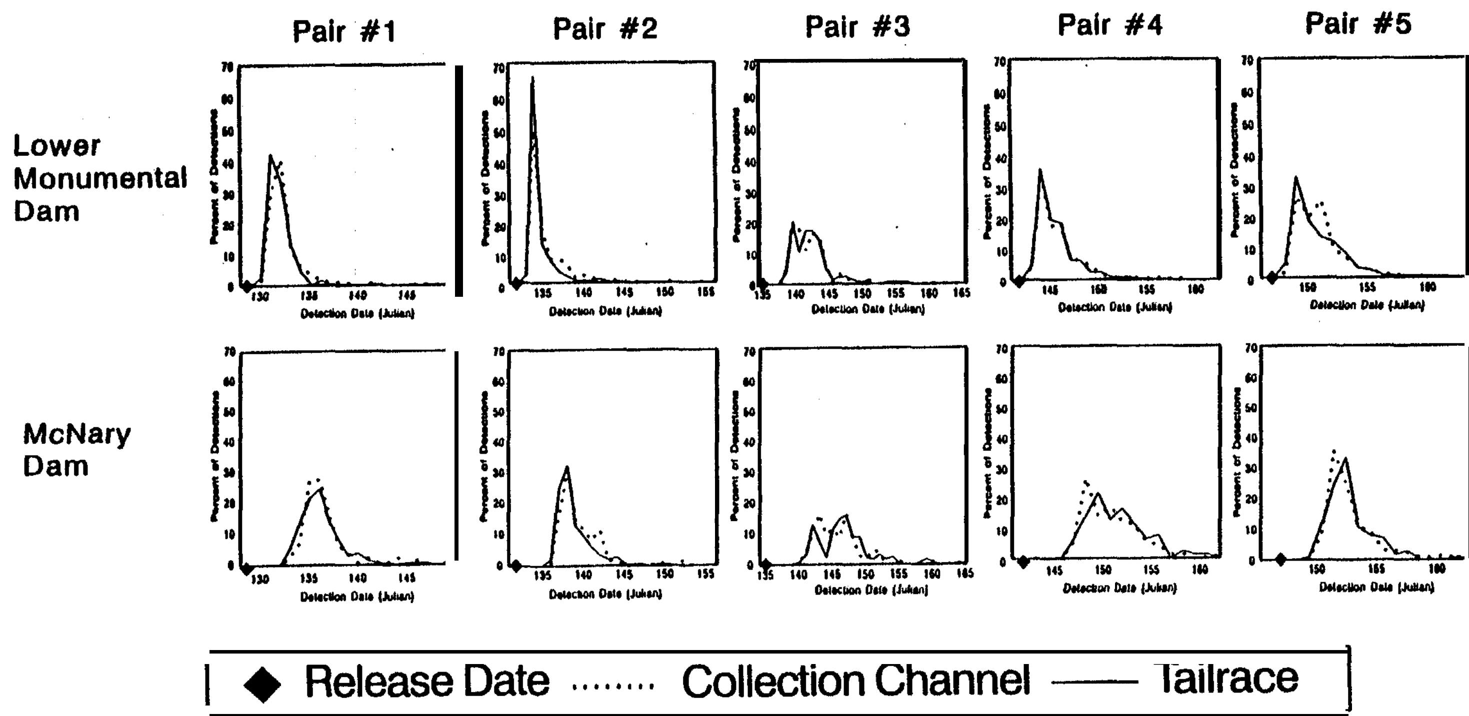
Passage distribution	Releases	χ^2	Degrees of freedom	P value*
Little Goose Dam	(R_{B11}, C_{B11})	20.26	17	0.236
	(R_{B12}, C_{B12})	17.52	17	0.409
	(R_{B13}, C_{B13})	10.89	20	0.588
	(R_{B14}, C_{B14})	27.78	17	0.023
Lower Monumental Dam	(R_{B11}, C_{B11})	29.73	17	0.016
	(R_{B12}, C_{B12})	19.11	15	0.184
	(R_{B13}, C_{B13})	14.81	14	0.380
	(R_{B14}, C_{B14})	25.61	17	0.049
McNary Dam	(R_{B11}, C_{B11})	27.47	18	0.054
	(R_{B12}, C_{B12})	29.47	21	0.066
	(R_{B13}, C_{B13})	9.43	9	0.409
	(R_{B14}, C_{B14})	7.76	14	0.941

* To control experiment-wise Type I error rate (e.g., $\alpha_{EX} = 0.05$), test-wise P values are compared to adjusted significance levels for four tests (e.g., $\alpha_T = 0.0127$) (see Table 9).

Appendix Table A19. Tests of homogeneity of passage distributions at downstream dams for Lower Granite Dam paired bypass releases of hatchery steelhead. P values calculated using Monte Carlo approximation of the exact method.

Passage distribution	Releases	χ^2	Degrees of freedom	P value
Little Goose Dam	(R_{B11}, C_{B11})	13.99	18	0.774
	(R_{B12}, C_{B12})	28.85	18	0.025
	(R_{B13}, C_{B13})	15.78	14	0.314
	(R_{B14}, C_{B14})	19.26	17	0.297
	(R_{B15}, C_{B15})	39.30	18	<0.001
Lower Monumental Dam	(R_{B11}, C_{B11})	22.40	21	0.375
	(R_{B12}, C_{B12})	16.6	20	0.739
	(R_{B13}, C_{B13})	26.41	18	0.072
	(R_{B14}, C_{B14})	18.07	24	0.889
	(R_{B15}, C_{B15})	23.26	21	0.319
McNary Dam	(R_{B11}, C_{B11})	18.34	17	0.357
	(R_{B12}, C_{B12})	8.60	15	0.915
	(R_{B13}, C_{B13})	25.27	19	0.117
	(R_{B14}, C_{B14})	18.64	17	0.336
	(R_{B15}, C_{B15})	17.99	17	0.383

* To control experiment-wise Type I error rate (e.g., $\alpha_{EX} = 0.05$), test-wise P values are compared to adjusted significance levels for five tests (e.g., $\alpha_T = 0.0102$) (see Table 9).



Appendix Figure A3. Passage distributions at downstream dams for Little Goose Dam paired bypass releases of hatchery steelhead.

Appendix Table A20. Tests of homogeneity of passage distributions at downstream dams for Lower Granite Dam turbine treatment releases and corresponding reference releases of hatchery yearling chinook salmon. P values calculated using Monte **Carlo** approximation of the exact method.

a) Turbine treatment, bypass reference, and draft tube reference.

Passage distribution	Releases	χ^2	Degrees of freedom	P value
Little Goose Dam	$(R_{411}, C_{411}, D_{411})$	94.55	46	<0.001
	$(R_{412}, C_{412}, D_{412})$	96.26	42	co.001
Lower Monumental Dam	$(R_{411}, C_{411}, D_{411})$	85.01	44	co.00 1
	$(R_{412}, C_{412}, D_{412})$	47.51	44	0.315
McNary Dam	$(R_{411}, C_{411}, D_{411})$	108.00	48	<0.001
	$(R_{412}, C_{412}, D_{412})$	48.83	42	0.214

* To control experiment-wise Type I error rate (e.g., $\alpha_{EX} = 0.05$), test-wise P values are compared to adjusted significance levels for two tests (e.g., $\alpha_T = 0.0253$) (see Table 9).

Appendix Table A20. Continued.

b) Turbine treatment and draft tube reference.

Passage distribution	Releases	χ^2	Degrees of freedom	P value
Little Goose Dam	(R_{411}, D_{411})	33.28	23	0.056
	(R_{412}, D_{412})	24.85	21	0.242
Lower Monumental Dam	(R_{411}, D_{411})	25.33	22	0.263
	(R_{412}, D_{412})	16.81	22	0.821
McNary Dam	(R_{411}, D_{411})	29.40	23	0.146
	(R_{412}, D_{412})	24.56	21	0.241

* To control .experiment-wise Type I error rate (e.g., $\alpha_{EX} = 0.05$), test-wise P values are compared to adjusted significance levels for two tests (e.g., $\alpha_T = 0.0253$) (see Table 9).

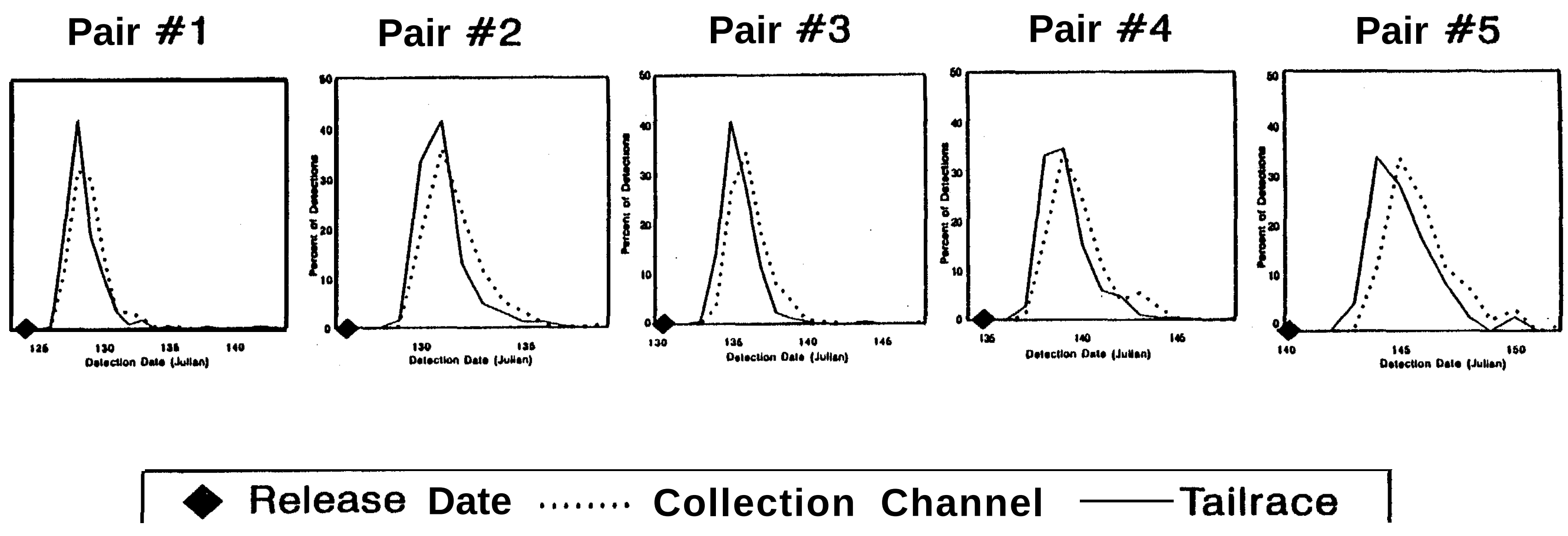
(Table A21). However, comparison of passage distributions shows that the actual differences were very small (Fig. A4). The statistical significance of the difference was a reflection of the highly sensitive nature of the test; the small actual difference was not likely to result in differences in survival or capture probabilities downstream from release.

McNary Dam passage distributions were significantly diierent (α_{EX} = 0.05) for the second and third paired bypass and reference releases of hatchery yearling chinook salmon (Table A22). Passage distributions at McNary Dam for the first paired releases of hatchery steelhead from Lower Monumental Dam were also significantly diierent (Table A23). However, comparison of passage distributions shows a maximum difference of 1 day in the passage of the 2 groups (Figs. A5 and A6). The effects of such small differences on survival and detection rates below Lower Monumental Dam were probably negligible.

Appendix Table A21. Tests of homogeneity of passage distributions at downstream dams for Little Goose Dam paired bypass releases of hatchery steelhead. P values calculated using Monte Carlo approximation of the exact method.

Passage distribution	Releases	χ^2	Degrees of freedom	P value
Lower Monumental Dam	(R_{B21}, C_{B21})	32.87	13	<0.001
	(R_{B22}, C_{B22})	47.94	19	<0.001
	(R_{B23}, C_{B23})	26.70	22	0.180
	(R_{B24}, C_{B24})	7.84	16	0.975
	(R_{B25}, C_{B25})	32.12	16	0.002
McNary Dam	(R_{B21}, C_{B21})	14.93	15	0.462
	(R_{B22}, C_{B22})	13.34	15	0.620
	(R_{B23}, C_{B23})	11.16	16	0.867
	(R_{B24}, C_{B24})	9.17	12	0.754
	(R_{B25}, C_{B25})	12.88	13	0.473

* To control experiment-wise Type I error rate (e.g., $\alpha_{EX} = 0.05$), test-wise P values are compared to adjusted significance levels for five tests (e.g., $\alpha_T = 0.0102$) (See Table 9).



Appendix Figure A4. Passage distributions at McNary Dam for Lower Monumental Dam paired bypass releases of hatchery chinook salmon.

Appendix Table A22. Tests of homogeneity of passage distributions at McNary Dam for Lower Monumental Dam paired bypass releases of hatchery yearling chinook salmon. P values calculated using Monte Carlo approximation of the exact method.

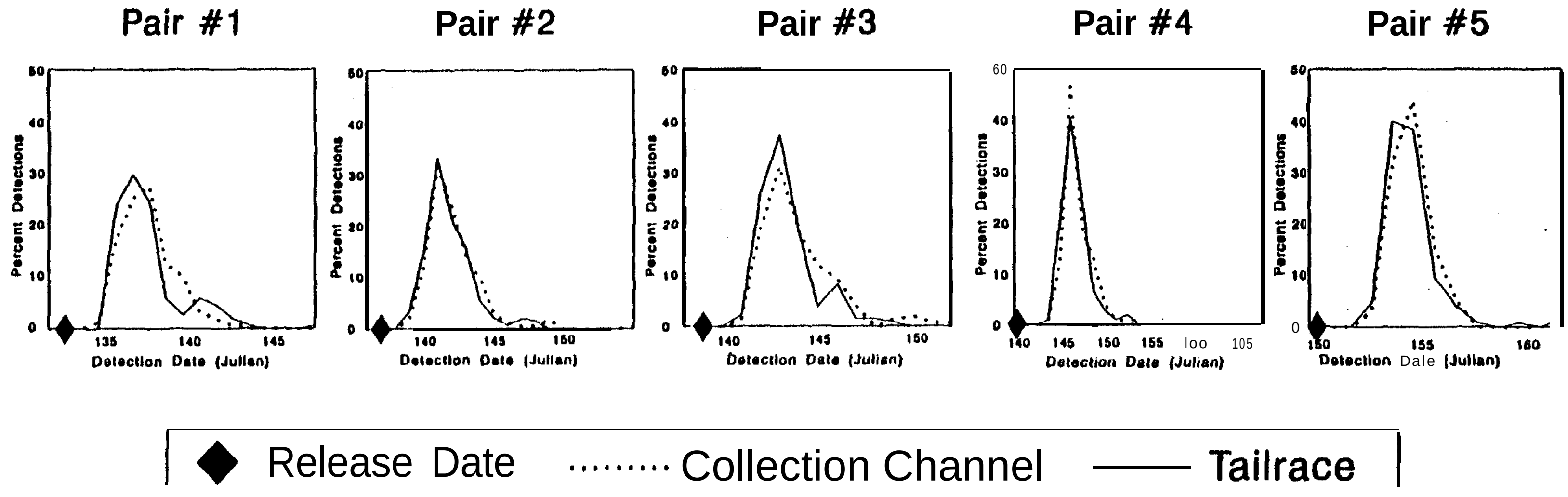
Passage distribution	Releases	χ^2	Degrees of freedom	P value*
McNary Dam	(R_{B31}, C_{B31})	26.04	13	0.004
	(R_{B32}, C_{B32})	37.97	10	<0.001
	(R_{B33}, C_{B33})	37.61	11	<0.001
	(R_{B34}, C_{B34})	7.76	14	0.939
	(R_{B35}, C_{B35})	20.41	8	0.003

* To control experiment-wise Type I error rate (e.g., $\alpha_{EX} = 0.05$), test-wise P values are compared to adjusted significance levels for five tests (e.g., $\alpha_T = 0.0102$) (see Table 9).

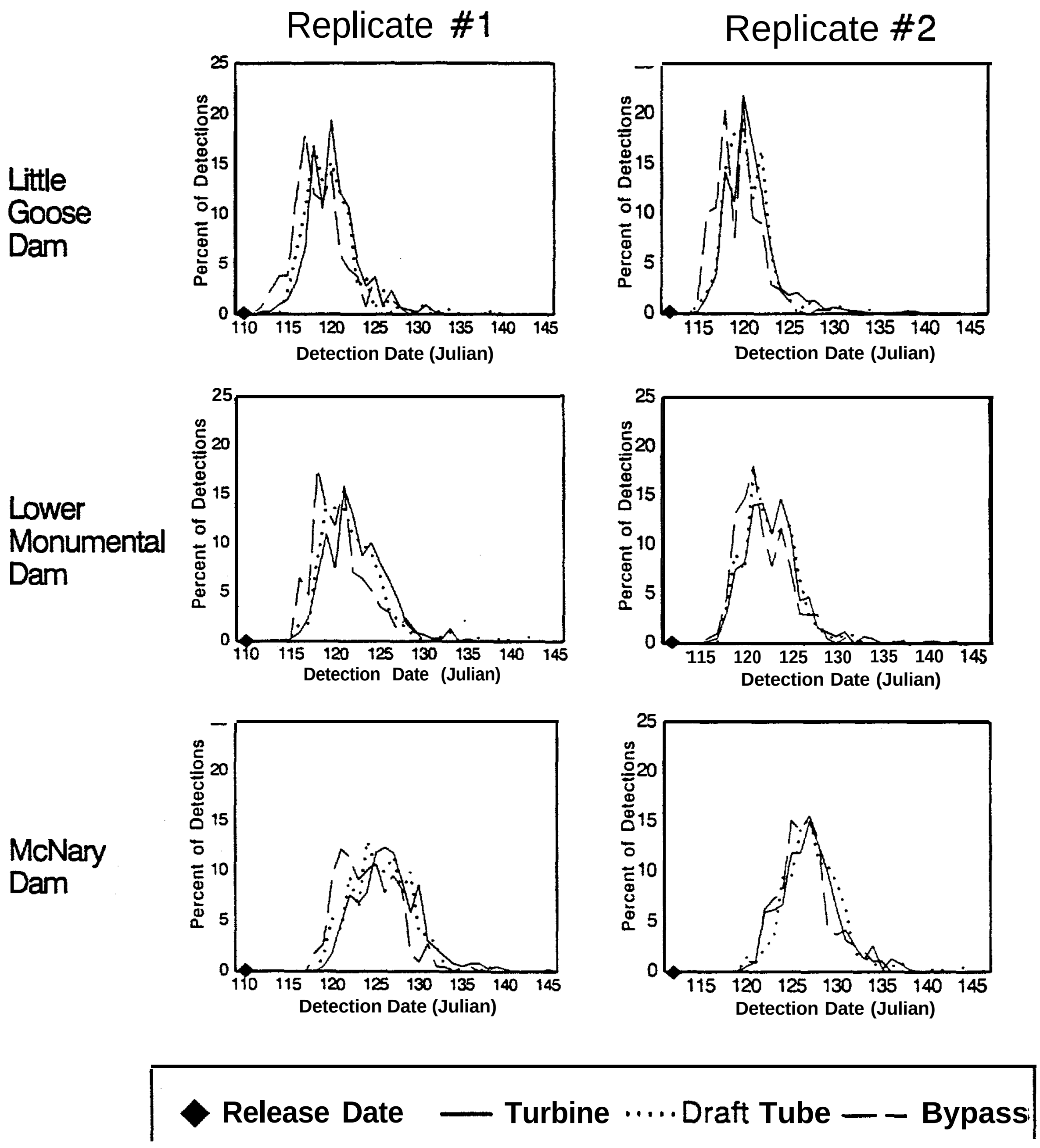
Appendix Table A23. Tests of homogeneity of passage distributions at McNary Dam for Lower Monumental Dam paired bypass releases of hatchery steelhead. P values calculated using Monte Carlo approximation of the exact method.

Passage distribution	Releases	χ^2	Degrees of freedom	P value*
McNary Dam	(R_{B31}, C_{B31})	20.18	10	0.015
	(R_{B32}, C_{B32})	9.76	11	0.586
	(R_{B33}, C_{B33})	17.11	II	0.070
	(R_{B34}, C_{B34})	10.85	10	0.378
	(R_{B35}, C_{B35})	6.38	7	0.510

* To control experiment-wise Type I error rate (e.g., $\alpha_{EX} = 0.05$), test-wise P values are compared to adjusted significance levels for five tests (e.g., $\alpha_T = 0.0102$) (see Table 9).



Appendix Figure A5. Passage distributions at McNary Dam for Lower Monumental Dam paired bypass releases of hatchery steelhead.



Appendix Figure A6. Passage distributions at downstream dams for Lower Granite Dam turbine, draft tube and bypass releases of hatchery chinook salmon.

APPENDIX B -- DATA BASE PREPARATION

Appendix Table B1. Number of hatchery yearling chinook salmon PIT tagged and released in Lower Granite Reservoir near the Port of Wilma, 9 April-5 May 1995. Fish eliminated from analyses for various reasons, and post-tagging mortalities are shown.

Release		R_{P1}	R_{P2}	R_{P3}	R_{P4}	R_{P5}	R_{P6}	R_{P7}	R_{P8}	R_{P9}	R_{P10}	R_{P11}	R_{P12}	Total
Release date		9 Apr	11 Apr	15 Apr	18 Apr	20 Apr	23 Apr	25 Apr	27 Apr	29 Apr	1 May	3 May	5 May	
Total fish in tagging files		1,250	781	1,183	568	691	1,246	1,260	1,223	1,065	1,210	455	119	11,051
Detections "out of order"		3	1	0	0	3	0	1	2	1	2	0	0	13
Detection before release		0	0	0	0	0	0	0	1	0	0	0	0	1
Handling mortality	(#)	17	2	1	2	2	7	1	0	2	2	0	0	36
	(%)	1.4	0.3	0.1	0.4	0.3	0.6	0.1	0.0	0.2	0.2	0.0	0.0	0.3
Total rejected	(#)	20	3	1	2	5	7	2	3	3	4	0	0	50
	(%)	1.6	0.4	0.1	0.4	0.7	0.6	0.2	0.2	0.3	0.3	0.0	0.0	0.5
Total fish in analysis		1,230	778	1,182	566	686	1,239	1,258	1,220	1,062	1,206	455	119	11,001

Appendix Table B2. Number of hatchery steelhead PIT tagged and released in Lower Granite Reservoir near the Port of Wilma, 22-April-12 May 1995. Fish eliminated from analyses for various reasons, and post-tagging mortalities are shown.

Release		R_{P1}	R_{P2}	R_{P3}	R_{P4}	R_{P5}	R_{P6}	R_{P7}	R_{P8}	R_{P9}	R_{P10}	R_{P11}	Total
Release date		22 Apr	24 Apr	26 Apr	28 Apr	30 Apr	2 May	4 May	6May	9May	11 May	12 May	
Total fish in tagging files		1,132	1,007	1,214	1,195	1,250	1,183	1,050	1,240	874	827	148	11,120
Detections "out of order"		2	2	0	2	1	0	0	0	0	0	0	7
Detection before release		0	0	2	0	0	0	1	0	0	0	0	3
Handling mortality	(#)	0	0	0	0	0	0	0	0	0	1	0	1
	(%)	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.1	0.0	0.01
Total rejected	(#)	2	2	2	2	1	0	1	0	0	1	0	11
	(%)	0.2	0.2	0.2	0.2	0.1	0.0	0.1	0.0	0.0	0.1	0.0	0.1
Total fish in analysis		1,130	1,005	1,212	1,193	1,249	1,183	1,049	1,240	874	826	148	11,109

Appendix Table B3. Number of hatchery yearling chinook salmon PIT tagged and released at Lower Granite Dam to evaluate post-detection survival in the bypass system during 1995. Fish eliminated from analyses for various reasons, and post-tagging mortalities are shown.

Release	R_{B11}	C_{B11}	R_{B12}	C_{B12}	R_{B13}	C_{B13}	R_{B14}	C_{B14}	Total
Release date	18 Apr	18 Apr	21 Apr	21 Apr	9 May	9 May	16 May	16 May	
Total fish in tagging files	979	777	882	813	918	720	869	771	6,729
Transported from release site	126	1	132	1	117	0	87	1	465
Unknown route at release site	0	0	3	0	4	0	4	0	11
Detection before release	0	0	0	0	0	0	3	1	4
Detections "out of order"	0	0	2	0	0	0	0	0	2
Handling mortality (number)	6	2	6	34	20	18	8	2	96
Handling mortality (%)	0.6	0.3	0.7	4.2	2.2	2.5	0.9	0.3	1.4
Total rejected (number)	132	3	143	35	141	18	102	4	578
Total rejected (%)	13.5	0.4	16.2	4.3	15.4	2.5	11.7	0.5	8.6
Total fish in analysis	847	774	739	778	777	702	767	767	6,151

Appendix Table B4. Number of hatchery steelhead PIT tagged and released at Lower Granite Dam to evaluate post-detection survival in the bypass system during 1995. Fish eliminated from analyses for various reasons, and post-tagging mortalities are shown.

Release	R_{B11}	C_{B11}	R_{B12}	C_{B12}	R_{B13}	C_{B13}	R_{B14}	C_{B14}	R_{B15}	C_{B15}	Total
Release date	28 Apr	28 Apr	2 May	2 May	5 May	5 May	10 May	10 May	17 May	17 May	
Total fish in tagging files	853	752	855	762	815	756	866	759	821	740	7,979
Transported from release site	65	0	144	1	92	0	78	0	61	0	441
Unknown route at release site	2	0	13	0	1	0	2	0	0	0	18
Handling mortality (number)	0	0	1	2	3	2	1	0	0	1	10
Handling mortality (%)	0.0	0.0	0.1	0.3	0.4	0.3	0.1	0.0	0.0	0.1	0.1
Total rejected (number)	67	0	158	3	96	2	81	0	61	1	469
Total rejected (%)	7.9	0.0	18.5	0.4	11.8	0.3	9.4	0.0	7.4	0.1	5.9
Total fish in analysis	786	752	697	759	719	754	785	759	760	739	7,510

Appendix Table B5. Number of hatchery yearling chinook salmon PIT tagged and released at Lower Granite Dam to evaluate turbine passage survival during 1995. Fish eliminated from analyses for various reasons, and post-tagging mortalities are shown.

Release	R_{41}	C_{41}	D_{41}	R_{42}	C_{42}	D_{42}	Total
Release date	20 Apr	20 Apr	20 Apr	22 Apr	22 Apr	22 Apr	
Total fish in tagging files	1,616	802	802	1,646	804	808	6,478
Transported from release site	0	0	0	2	3	0	5
Detection before release	0	0	0	1	2	2	5
Detections "out of order"	0	0	0	2	0	0	2
Handling mortality (number)	11	16	22	10	5	5	69
Handling mortality (%)	0.7	2.0	2.7	0.6	0.6	0.6	1.1
Total rejected (number)	11	16	22	15	10	7	81
Total rejected (%)	0.7	2.0	2.7	0.9	1.2	0.9	1.3
Total fish in analysis	1,605	786	780	1,631	794	801	6,397

Appendix Table B6. Number of hatchery steelhead PIT tagged and released at Little Goose Dam to evaluate post-detection survival in the bypass system during 1995. Fish eliminated from analyses for various reasons, and post-tagging mortalities are shown.

Release	R_{B21}	C_{B21}	R_{B22}	C_{B22}	R_{B23}	C_{B23}	R_{B24}	C_{B24}	R_{B25}	C_{B25}	Total
Release date	9 May	9 May	12 May	12 May	16 May	16 May	22 May	22 May	27 May	27 May	
Total fish in tagging files	859	773	860	751	865	762	863	641	863	739	7,976
Transported from release site	220	0	417	1	200	0	258	0	81	0	1,177
Unknown route at release site	14	0	II	0	0	0	0	0	1	0	26
Handling (number)	4	0	1	6	0	1	4	5	2	0	23
mortality (%)	0.5	0.0	0.1	0.8	0.0	0.1	0.5	0.8	0.2	0.0	0.3
Total (number)	238	0	429	7	200	1	262	5	84	0	1,226
rejected **(%)**	27.7	0.0	49.9	0.9	23.1	0.1	30.4	0.8	9.7	0.0	15.4
Total fish in analvsis	621	773	431	744	665	761	601	636	779	739	6,750

Appendix Table B7. Number of hatchery yearling chinook salmon PIT tagged and released at Lower Monumental Dam to evaluate post-detection survival in the bypass system during 1995. Fish eliminated from analyses for various reasons, and post-tagging mortalities are shown.

Release	R_{B31}	C_{B31}	R_{B32}	C_{B32}	R_{B33}	C_{B33}	R_{B34}	C_{B34}	R_{B35}	C_{B35}	Total
Release date	4 May	4 May	7 May	7 May	11 May	11 May	15 May	15 May	21 May	21 May	
Total fish in tagging files	884	772	892	747	860	763	853	756	862	761	8,150
Transported from release site	11	2	58	0	17	0	26	0	26	0	140
Unknown route at release site	3	0	1	0	1	0	5	0	1	0	11
Handling mortality (number)	1	0	1	6	2	3	3	4	1	1	22
Handling mortality (%)	0.1	0.0	0.1	0.8	0.2	0.4	0.4	0.5	0.1	0.1	0.3
Total rejected (number)	15	2	60	6	20	3	34	4	28	1	173
Total rejected (%)	1.7	0.3	6.7	0.8	2.3	0.4	4.0	0.5	3.2	0.1	2.1
Total fish in analysis	869	770	832	741	840	760	819	752	834	760	7,977

Appendix Table B8. Number of hatchery steelhead PIT tagged and released at Lower Monumental Dam to evaluate post-detection survival in the bypass system during 1995. Fish eliminated from analyses for various reasons, and post-tagging mortalities are shown.

Release	R_{B31}	C_{B31}	R_{B32}	C_{B32}	R_{B33}	C_{B33}	R_{B34}	C_{B34}	R_{B35}	C_{B35}	Total
Release date	13 May	13 May	17 May	17 May	19 May	19 May	26May	26 May	31 May	31 May	
Total fish in tagging files	863	773	853	763	859	750	837	706	849	779	8,032
Transported from release site	12	0	27	0	22	0	18	0	40	0	119
Unknown route at release site	6	0	1	0	1	0	3	0	1	0	12
Detection before release	0	1	0	0	0	0	0	0	0	0	1
Handling (number)	0	0	0	3	2	3	4	7	4	11	34
mortality (%)	0.0	0.0	0.0	0.4	0.2	0.4	0.5	1.0	0.5	1.4	0.4
Total (number)	18	1	28	3	25	3	25	7	45	11	166
rejected (%)	2.1	0.1	3.3	0.4	2.9	0.4	3.0	1.0	5.3	1.4,	2.1
Total fish in analysis	845	772	825	760	834	747	812	699	804	768	7,866

APPENDIX C -- SURVIVAL ESTIMATES FOR DAILY RELEASES INTO LOWER GRANITE DAM TAILRACE

Appendix Table Cl. Estimates of survival probabilities for daily releases of hatchery yearling chinook into the **tailrace** of Lower Granite Dam for comparison with transported smolts. Estimates based on the Single-Release Model. Standard errors in parentheses. Abbreviations: LGR-Lower Granite Dam; LGO-Little Goose Dam; LMO-Lower Monumental Dam; **MCN-McNary** Dam.

Date	Number released	LGR to LGO (S_{R2})		LGO to LMO (S_{R3})		LGR to LMO (S_{R4})	
9 Apr	81	0.991	(0117)	0844	(0166)	0836	(0 117)
10 Apr	51	0882	(0.180)	0892	(0317)	0787	(0221)
II Apr	90	0841	(0.085)	1.196	(0275)	1 005	(0216)
12 Apr	211	0.701	(0.055)	1.218	(0.199)	0 853	(0 131)
13 Apr	291	0.871	(0.088)	0.909	(0 152)	0.792	(0.099)
14 Apr	550	0.947	(0.120)	0.177	(0 137)	0735	(0079)
15 Apr	597	0.995	(0 124)	0.821	(0 138)	0817	(0079)
16 Apr	427	0907	(0.118)	0822	(0 144)	0746	(0.076)
17 Apr	629	0.915	(0.085)	0.951	(0 125)	0870	(0.075)
18 Apr	2250	0 865	(0019)	0998	(0067)	0863	(0041)
19 Apr	3734	0.955	(0039)	0922	(0055)	0881	(0035)
20 Apr	2238	0 898	(0039)	0998	(0070)	0896	(0047)
21 Apr	2171	0.857	(0.033)	0910	(0056)	0779	(0036)
22 Apr	3012	0855	(0025)	0989	(0052)	0846	(0036)
23 Apr	290S	0872	(0.024)	0973	(0048)	0848	(0035)
24 Apr	2297	0.836	(0.024)	1033	(0 058)	0864	(0041)
25 Apr	2753	0838	(0022)	0916	(0047)	0784	(0034)
26Apr	1476	0865	(0019)	0971	(0041)	0840	(0012)
21Apr	3469	0884	(0020)	0 945	(0042)	0835	(0 031)
28Apr	3815	0889	(0020)	0957	(0038)	0850	(0028)
29Apr	5663	0.888	(0015)	0944	(0029)	0818	(0021)
30 Apr	5238	0879	(0.015)	0949	(0029)	0834	(0021)
I May	6815	0884	(0013)	0922	(0023)	0815	(0017)
2 May	S349	0.895	(0013)	0.915	(0024)	0.818	(0017)
3 May	2271	0927	(0024)	0.851	(0034)	0789	(0023)
4 May	7123	0.914	(0.013)	0.909	(0022)	0832	(0016)
5 May	6262	0921	(0016)	0908	(0027)	0837	(0019)
6 May	3550	0.909	(0020)	0936	(0017)	0850	(0027)
7 May	5494	0902	(0014)	0897	(0025)	0.809	(0018)
8 May	3792	0854	(0017)	0879	(0029)	0751	(0020)
9 May	2138	0 8 %	(0023)	0932	(0041)	0835	(0029)
10 May	2824	0.880	(0 031)	0 969	(0050)	0851	(0011)
II May	3110	0 853	(0 029)	1 004	(0 051)	0857	(0012)
12 May	1220	0823	(0046)	0847	(0068)	0697	(0041)
13 May	No fish released						
14 May	1041	0928	(0 051)	0 92,	(0 089)	0857	(0066)
IS May	651	0831	(0055)	1 087	(0 141)	0905	(0 101)
16 May	543	0 850	(0 075)	0 951	(0 143)	0808	(0007)
17 May	784	0 814	(0 051)	0971	(0 105)	0791	(0070)
18 May	441	0890	(0067)	0078	(0 118)	0781	(0084)
19 May	388	0 810	(0069)	0865	(0 129)	0701	(0086)
20 May	322	0869	(OOSO)	1 055	(0 135)	0917	(0 106)

Date	Number released	LGR to LGO (S_{R2})		LGO lo LMO (S_{R3})		LGR to LMO (S_{R4})	
21 May	No fish released						
22May	No fish released						
23 May	No fish released.						
24May	No fish released.						
25 May	855	0.927	(0047)	0.834	(0088)	0773	(0.069)
26 May	200	0.764	(0.081)	0.899	(0167)	0686	(0.109)
27May	322	0769	(0.073)	1.243	(0.403)	0.956	(0296)
28 May	No fish released						
29May	274	0.929	(0 124)	1.209	(0388)	1.124	(0323)
30 May	450	0.939	(0.091)	0.747	(0.132)	0.701	(0.099)
31 May	112	0892	(0.149)	0746	(0216)	0666	(0 154)
I Jun	120	0.981	(0221)	0.549	(0.170)	0.519	(0.106)
2 Jun	184	0779	(0.077)	0.982	(0.200)	0.766	(0.140)
3 Jun	94	0.936	(0 174)	0.786	(0.236)	0736	(0.168)
4 Jun	235	0.923	(0.076)	0.716	(0.098)	0660	(0071)
5 Jun	251	0.854	(0.054)	1.048	(0 165)	0894	(0.131)
6 Jun	121	0.915	(0050)	1020	(0. 113)	0.933	(0094)
7 Jun	132	0.912	(0041)	0994	(0 128)	0906	(0.112)
8 Jun	116	0892	(0061)	0.723	(0.095)	0645	(0.074)
9 Jun	82	0789	(0060)	1.418	(0.504)	1.119	(0.397)
10 Jun	67	0.800	(0.081)	1.048	(0.284)	0838	(0220)
11 Jun	63	0934	(0.106)	0706	(0 191)	0659	(0 155)
12 Jun	46	0.840	(0072)	1.360	(0538)	I 142	(0450)
13 Jun	39	0.829	(0.118)	0776	(0.218)	0644	(0 160)
14 Jun	19	0.987	(0 193)	1.206	(0807)	I 190	(0740)
15 Jun	21	2 905	(2.288)	0 150	(0.176)	0416	(0.316)
16 Jun	17	Insufficient detections					
17 Jun	45	1.256	(0 179)	0.800	(0.605)	1.004	(0.721)
18 Jun	31	0919	(0266)	0491	(0.210)	0.451	(0 130)
19 Jun	20	4.050	(1.416)	0.128	(0 130)	0 517	(0.212)
20 Jun	SO	0.807	(0.097)	0770	(0393)	0622	(0309)
21 Jun	34	0.533	(0099)	1.052	(0 396)	OS60	(0 226)
22Jun	48	0736	(0087)	1.086	(0226)	0799	(0 169)
23 Jun	40	0819	(0 136)	1 328	(0672)	1.087	(0 524)
24 Jun	28	0.690	(0092)	0857	(0094)	0 592	(0097)
25 Jun	22	0795	(0 115)	0667	(0 136)	0 530	(0 108)
26 Jun	IO	0667	(0 192)	0900	(0 506)	0600	(0 346)
27 Jun	10	1.500	(1.031)	0600	(0607)	0900	(0589)
28 Jun	16	Insufficient detections					
29 Jun	23	Insufficient detections					
30 Jun	21	Insufficient detections					
I Jul	6	Insufficient detections					

Appendix Table C2. Estimates of survival probabilities for daily releases of wild yearling chinook into the **tailrace** of Lower Granite Dam for comparison with transported smolts. Estimates based on the Single-Release Model, Standard errors in parentheses, Abbreviations: LGR-Lower Granite Dam; LGO-Little Goose Dam; LMO-Lower Monumental Dam; MCN-McNary Dam.

Date	Number released	LGR to LGO (S_{R2})		LGO to LMO (S_{R3})		LGR to LMO (S_{R4})	
9Apr	186	0.872	(0.044)	0 816	(0 087)	0712	(0 067)
10 Apr	195	0.864	(0034)	1.584	(0 3 2 5)	1 369	(0.279)
II Apr	380	0.877	(0027)	0942	(0 064)	0826	(0052)
12 Apr	579	0.872	(0030)	0865	(0060)	0754	(0 044)
13 Apr	616	0.902	(0045)	0823	(0077)	0743	(0056)
14 Apr	861	0902	(0055)	0867	(0 091)	0782	(0 060)
IS Apr	1041	0825	(0052)	0959	(0099)	0791	(0 061)
16 Apr	749	0.984	(0 108)	0886	(0146)	0872	(0 095)
17 Apr	1107	0858	(0067)	0968	(0 113)	0811	(0 066)
18 Apr	2148	0751	(0043)	I 159	(0 0 9 5)	0870	(0050)
19 Apr	2167	0910	(0064)	0 888	(0 080)	0 808	(0040)
20 Apr	1140	0964	(0078)	0902	(0 100)	0 866	(0059)
21 Apr	1137	0.925	(0055)	0988	(0 092)	0914	(0 060)
22Apr	1107	0.877	(0048)	0986	(0082)	0 864	(0050)
23 Apr	945	0891	(0053)	0845	(0 071)	0753	(0042)
24Apr	697	1.014	(0 066)	0.851	(0095)	0 863	(0072)
25 Apr	602	0857	(0045)	I 163	(0 128)	0997	(0 097)
26Apr	465	0805	(0 043)	0913	(0 090)	0735	(0063)
27 Apr	711	0854	(0.042)	0826	(0082)	0705	(0 060)
28 Apr	744	0853	(0040)	1 004	(0 094)	0.856	(0 070)
29 Apr	910	0.888	(0027)	l o b 5	(0 0 7 2)	0946	(0 058)
30 Apr	813	0994	(0039)	0718	(0048)	0734	(0015)
I May	827	0.917	(0030)	0952	(0055)	0873	(0 042)
2 May	760	0.902	(0026)	0898	(0050)	0809	(0039)
3 May	300	0.946	(0040)	1.004	(0 0 7 7)	0950	(0061)
4 u s y	864	0.896	(0025)	0934	(0042)	0837	(0 031)
5 May	1201	0 907	(0029)	0878	(0045)	0796	(0032)
6 May	435	0873	(0044)	0787	(0069)	0 687	(0 049)
7 May	651	0 859	(0031)	0914	(0062)	0 802	(0045)
8 May	513	0864	(0031)	0 908	(0 058)	0 785	(0041)
9 May	265	0897	(0044)	1020	(0 116)	0914	(0 094)
10 May	470	0855	(0.052)	1 017	(0 094)	0870	(0 062)
II May	466	0859	(0057)	1 031	(0 100)	0 886	(0 064)
12 May	492	0878	(0044)	0846	(0 065)	0743	(0041)
13 May	No fish released						
14 May	271	0998	(0088)	0776	(0114)	0714	(0082)
15 May	215	0.906	(0 093)	1 038	(0 206)	0940	(0 157)
16 May	160	0.915	(0081)	0819	(0 116)	0768	(0079)
17 May	174	1072	(0 128)	0769	(0 160)	0825	(0 123)
18 May	75	0876	(0 113)	0745	(0 158)	0653	(0 108)
19 May	83	0.982	(0 153)	0845	(0214)	0830	(0 152)
20 May	55	0945	(0 117)	0.885	(0 175)	0817	(0 125)
21 May	No fish released						
22May	No fish released						
23 May	No lirh released.						
24 May	No fish released						
25 May	402	0932	(0.045)	0.860	(0.085)	0.802	(0.066)
26May	123	0948	(0097)	0.853	(0203)	0809	(0 167)
27May	152	0.770	(0.060)	1.016	(0 154)	0.782	(0.110)
28 May	Nolish released						
29May	240	0874	(0046)	0963	(0 105)	0.842	(0084)
30 May	350	0835	(0051)	0.777	(0079)	0.649	(0 055)
31 May	115	0868	(0081)	0.682	(0 104)	0592	(0073)
I Jun	71	0780	(0082)	0933	. (0 138)	0728	(0 102)
2 Jun	87	"8 3 3	(0 0 6 9)	0.946	(0.187)	0788	(0 147)
3 Jun	57	I 166	(0 2 1 5)	0.570	(0.156)	0664	(0109)
4 Jun	161	0.839	(0042)	l o o 4	(0 0 8 4)	0843	(0069)
5 Jun	210	1.007	(0 0 4 2)	0.877	(0085)	0883	(0073)
6 Jun	139	0944	(0049)	0834	(0.076)	0787	(0.060)
7 Jun	225	0.879	(0032)	0837	(0058)	0 737	(0 049)
8 Jun	218	0923	(0033)	0799	(0060)	0.737	(0.050)
9 Jun	122	0877	(0042)	0.934	(0.090)	0 819	(0077)
10 Jun	147	0837	(0048)	0.987	(0.155)	0826	(0 126)
II Jun	120	0900	(0051)	0.730	(0092)	0657	(0074)
12 Jun	112	0866	(0.051)	0862	(0.110)	0746	(OOYQ)
13 Jun	89	0.913	(0069)	0.630	(0 085)	0 575	(0063)
14 Jun	57	0939	(0.115)	0695	(0 144)	0653	(0 103)
15 Jun	32	0740	(0086)	1.034	(0 121)	0764	(0 117)
16 Jun	33	0778	(0.101)	0.838	(0323)	0652	(0 246)
17 Jun	51	0.922	(0.118)	1076	(0403)	0991	(0345)
18 Jun	48	0.799	(0.078)	0829	(0.169)	0663	(0 133)
19 Jun	51	0875	(0.102)	0763	(0 171)	0668	(0 129)
20 Jun	87	0847	(OOS6)	0879	(0 123)	0.745	(0 101)
21 Jun	82	0.836	(0080)	0.709	(0.108)	0.593	(0 0 7 7)
22 Jun	105	0810	(0066)	0715	(0.078)	0 578	(0 055)
23 Jun	loo	0751	(0 050)	1005	(0.080)	0755	' (0070)
24 Jun	98	0 788	(0 062)	0767	(0 lob)	0604	(0080)
25 Jun	45	0822	(0084)	0562	(0 128)	0462	(0098)
26 Jun	32	0594	(0091)	I 148	(0 080)	0682	(0 114)
27 Jun	22	Insufficient detections					
28 Jun	21	0.7 1 4	(0 147)	I 133	(0 571)	0810	(0 406)
29 Jun	41	Insufficient detections					
30 Jun	47	0 7 3 0	(0 0 9 4)	0758	(0 154)	0554	(0109)
I Jul	34	0 9 3 5	(0 2 2 3)	0747	(0513)	0698	(0437)

APPENDIX D -- TRAVEL TIME AND MIGRATION RATE STATISTICS

Appendix Table D1. Travel times and migration rates between the Port of Wilma and Lower Granite Dam (49 km) for primary releases of hatchery yearling chinook salmon.

Release	Date	Number	Travel time (days)					Migration rate (km/day)				
			Minimum	20%	Median	80%	Maximum	Minimum	20%	Median	80%	Maximum
R_{P1}	9 Apr	509	3.33	9.05	15.72	19.46	34.41	1.42	2.52	3.12	5.41	14.71
R_{P2}	11 Apr	362	3.93	8.25	14.24	17.66	30.94	1.58	2.77	3.44	5.94	12.47
R_{P3}	15 Apr	461	3.86	11.63	15.24	22.14	40.03	1.22	2.21	3.22	4.21	12.69
R_{P4}	18 Apr	248	2.90	7.68	10.34	14.22	41.69	1.18	3.45	4.74	6.38	16.90
R_{P5}	20 Apr	325	2.51	7.29	9.30	12.29	31.30	1.57	3.99	5.27	6.72	19.52
R_{P6}	23 Apr	590	2.97	5.37	7.43	9.49	34.74	1.41	5.16	6.59	9.12	16.50
R_{P7}	25 Apr	584	2.11	4.26	5.99	7.42	26.58	1.84	6.60	8.18	11.50	23.22
R_{P8}	27 Apr	487	2.14	4.36	5.38	9.68	33.77	1.45	5.06	9.11	11.24	22.90
R_{P9}	29 Apr	382	2.32	3.61	6.51	10.16	25.64	1.91	4.82	7.53	13.57	21.12
R_{P10}	1 May	430	1.67	3.82	5.95	7.84	20.34	2.41	6.25	8.24	12.83	29.34
R_{P11}	3 May	136	1.99	4.29	5.54	7.63	26.51	1.85	6.42	8.84	11.42	24.62
R_{P12}	5 May	37	2.53	3.47	6.49	13.44	24.51	2.00	3.65	7.55	14.12	19.37

Appendix Table D2. Travel times and migration rates between the Port of Wilma and Lower Granite Dam (49 km) for primary releases of hatchery steelhead.

			Travel time (days)					Migration rate (km/day)				
Release	Date	Number	Minimum	20%	Median	80%	Maximum	Minimum	20%	Median	80%	Maximum
R_{P1}	22 Apr	870	2.40	3.64	5.16	8.87	40.01	1.22	5.52	9.50	13.46	20.42
R_{P2}	24 Apr	755	1.63	2.96	4.35	7.66	27.70	1.77	6.40	11.26	16.55	30.06
R_{P3}	26 Apr	946	1.56	2.74	4.29	6.03	56.39	0.87	8.13	11.42	17.88	31.41
R_{P4}	28 Apr	914	1.02	2.78	3.71	5.36	43.83	1.12	9.14	13.21	17.63	48.04
R_{P5}	30 Apr	865	1.23	2.53	3.01	4.95	19.85	2.47	9.90	16.28	19.37	39.84
R_{P6}	2 May	605	0.76	2.50	2.94	6.37	27.45	1.79	7.69	16.67	19.60	64.47
R_{P7}	4 May	522	1.38	2.03	2.87	4.57	19.88	2.46	10.72	17.07	24.14	35.51
R_{P8}	6 May	618	1.38	1.63	2.30	2.93	25.61	1.91	16.72	21.30	30.06	35.51
R_{P9}	9 May	436	1.20	1.59	2.06	3.42	26.10	1.88	14.33	23.79	30.82	40.83
R_{P10}	11 May	392	0.53	1.44	1.82	3.17	23.62	2.07	15.46	26.92	34.03	92.45
R_{P11}	12 May	73	1.39	1.65	2.23	4.09	12.10	4.05	11.98	21.97	29.70	35.25

Appendix Table D3. Travel times and migration rates between Lower Granite Dam and Little Goose Dam (60 km) for primary releases of hatchery yearling chinook salmon.

Release	Date	Number	Travel time (days)					Migration rate (km/day)				
			Minimum	20%	Median	80%	Maximum	Minimum	20%	Median	80%	Maximum
R_{P1}	9 Apr	129	2.84	4.47	6.43	9.24.	19.05	3.15	6.49	9.33	13.42,	21.13
R_{P2}	11 Apr	80	2.49	4.03	5.02	7.56	14.80	4.05	7.94	11.95	14.89	24.10
R_{P3}	15 Apr	122	2.32	4.21	6.02	8.10	13.35	4.49	7.41	9.97	14.25	25.86
R_{P4}	18 Apr	59	2.65	3.81	5.45	7.46	11.35	5.29	8.04	11.01	15.75	22.64
R_{P5}	20 Apr	105	2.17	3.81	5.12	6.51	17.97	3.34	9.22	11.72	15.75	27.65
R_{P6}	23 Apr	192	2.17	3.55	4.86	6.23	12.88	4.66	9.63	12.35	16.90	27.65
R_{P7}	25 Apr	194	2.07	3.59	4.49	5.99	18.35	3.27	10.02	13.36	16.71	28.99
R_{P8}	27 Apr	151	2.14	3.92	4.86	6.74	13.81	4.34	8.90	12.35	15.31	28.04
R_{P9}	29 Apr	108	2.29	3.65	4.79	6.58	16.03	3.74	9.12	12.53	16.44	26.20
R_{P10}	1 May	100	2.07	2.90	3.90	5.49	8.78	6.83	10.93	15.38	20.69	28.99
R_{P11}	3 May	28	1.99	3.10	4.29	6.29	16.59	3.62	9.54	13.99	19.35	30.15
R_{P12}	5 May	8	2.37	3.23	4.85	7.56	9.24	6.49	7.94	12.37	18.58	25.32

Appendix Table D4. Travel times and migration rates between Lower Granite Dam and Little Goose Dam (60 km) for primary releases of hatchery steelhead.

			Travel time (days)					Migration rate (km/day)				
Release	Date	Number	Minimum	20%	Median	80%	Maximum	Minimum	20%	Median	80%	Maximum
R_{P1}	22 Apr	276	1.59	3.55	5.36	8.15	19.99	3.00	7.36	11.19	16.90	37.74
R_{P2}	24 Apr	254	1.82	3.78	5.79	8.98	28.01	2.14	6.68	10.36	15.87	32.97
R_{P3}	26 Apr	367	1.34	3.12	4.68	8.62	40.51	1.48	6.96	12.82	19.23	44.78
R_{P4}	28 Apr	330	1.73	2.85	4.30	7.37	18.43	3.26	8.14	13.95	21.05	34.68
R_{P5}	30 Apr	307	1.60	2.81	4.57	7.50	20.73	2.89	8.00	13.13	21.35	37.50
R_{P6}	2 May	208	1.61	2.37	3.28	6.05	20.61	2.91	9.92	18.29	25.32	37.27
R_{P7}	4 May	164	1.54	2.18	3.03	4.34	26.21	2.29	13.82	19.80	27.52	38.96
R_{P8}	6 May	205	1.30	2.11	2.65	3.94	15.31	3.92	15.23	22.64	28.44	46.15
R_{P9}	9 May	151	1.34	1.89	2.52	5.31	15.15	3.31	11.30	23.81	31.75	44.78
R_{P10}	11 May	152	1.60	2.41	3.33	6.54	28.24	2.12	9.17	18.02	24.90	37.50
R_{P11}	12 May	27	1.64	2.35	3.93	5.79	7.71	7.78	10.36	15.27	25.53	36.59

Appendix Table D5. Travel times and migration rates between Little Goose Dam and Lower Monumental Dam (46 km) for primary releas of hatchery yearling chinook salmon.

			Travel time (days)					Migration rate (km/day)				
Release	Date	Number	Minimum	20%	Median	80%	Maximum	Minimum	20%	Median	80%	Maximum
R_{P1}	9 Apr	119	1.20	1.96	2.61	3.23	6.13	7.50	14.24	17.62	23.47	38.33
R_{P2}	11 Apr	66	1.44	1.91	2.51	3.44	6.05	7.60	13.37	18.33	24.08	31.94
R_{P3}	15 Apr	114	1.27	1.77	2.36	3.11	13.18	3.49	14.79	19.49	25.99	36.22
R_{P4}	18 Apr	49	1.06	1.79	2.22	3.03	5.53	8.32	15.18	20.72	25.70	43.40
R_{P5}	20 Apr	85	1.28	1.75	2.21	2.95	4.47	10.29	15.59	20.81	26.29	35.94
R_{P6}	23 Apr	157	1.12	1.69	2.11	2.94	7.93	5.80	15.65	21.80	27.22	41.07
R_{P7}	25 Apr	171	1.18	1.61	1.94	2.61	6.65	6.92	17.62	23.71	28.57	38.98
R_{P8}	27 Apr	148	1.06	1.60	1.99	2.55	4.98	9.24	18.04	23.12	28.75	43.40
R_{P9}	29 Apr	134	1.12	1.56	1.77	2.41	5.79	7.94	19.09	25.99	29.49	41.07
R_{P10}	1 May	135	0.99	1.52	1.83	2.19	6.36	7.23	21.00	25.14	30.26	46.46
R_{P11}	3 May	39	1.13	1.47	1.85	2.18	3.29	13.98	21.10	24.86	31.29	40.71
R_{P12}	5 May	14	1.12	1.59	2.09	3.56	5.97	7.71	12.92	22.01	28.93	41.07

Appendix Table D6. Travel times and migration rates between Little Goose Dam and Lower Monumental Dam (46 km) for primary releas of hatchery steelhead.

			Travel time (days)					Migration rate (km/day)				
Release	Date	Number	Minimum	20%	Median	80%	Maximum	Minimum	20%	Median	80%	Maximum
R_{P1}	22 Apr	168	1.06	1.85	2.92	4.34	7.95	5.79	10.60	15.75	24.86	-43.40
R_{P2}	24 Apr	171	1.10	1.81	2.59	4.28	14.68	3.13	10.75	17.76	25.41	41.82
R_{P3}	26 Apr	235	1.01	1.84	2.64	4.32	16.79	2.74	10.65	17.42	25.00	45.54
R_{P4}	28 Apr	197	0.94	1.68	2.51	3.91	12.90	3.57	11.76	18.33	27.38	48.94
R_{P5}	30 Apr	233	1.01	1.60	2.31	3.97	14.78	3.11	11.59	19.91	28.75	45.54
R_{P6}	2 May	176	0.95	1.51	2.02	3.70	19.81	2.32	12.43	22.77	30.46	48.42
R_{P7}	4 May	143	1.14	1.80	2.74	4.86	12.83	3.59	9.47	16.79	25.56	40.35
R_{P8}	6 May	191	0.98	1.62	2.46	4.05	22.86	2.01	11.36	18.70	28.40	46.94
R_{P9}	9 May	149	1.21	1.62	2.39	4.53	23.61	1.95	10.15	19.25	28.40	38.02
R_{P10}	11 May	147	0.98	1.88	2.48	4.03	32.90	1.40	11.41	18.55	24.47	46.94
R_{P11}	12 May	23	1.11	1.73	2.41	4.71	7.67	6.00	9.77	19.09	26.59	41.44

Appendix Table D7. Travel times and migration rates between Lower Monumental Dam and McNary Dam (199 km) for primary releases hatchery yearling chinook salmon.

			Travel time (days)					Migration rate (km/day)				
Release	Date	Number	Minimum	20%	Median	80%	Maximum	Minimum	20%	Median	80%	Maximum
R_{P1}	9 Apr	102	2.78	3.72	4.36	5.39	10.50	11.33	22.08	27.29	3 1.99	42.81
R_{P2}	11 Apr	75	2.82	3.59	4.52	5.74	13.41	8.87	20.73	26.33	33.15	42.20
R_{P3}	15 Apr	84	2.38	3.27	4.06	5.82	12.84	9.27	20.45	29.3 I	36.39	50.00
R_{P4}	18 Apr	48	2.65	3.86	4.35	5.92	14.70	8.10	20.10	27.36	30.83	44.91
R_{P5}	20 Apr	73	2.78	3.47	4.50	5.59	7.45	15.97	21.29	26.44	34.29	42.81
R_{P6}	23 Apr	138	2.52	3.46	4.11	5.05	10.87	10.95	23.56	28.95	34.39	47.22
R_{P7}	25 Apr	134	2.54	3.27	3.87	4.84	20.47	5.81	24.59	30.75	36.39	46.85
R_{P8}	27 Apr	101	2.32	3.33	4.17	5.24	9.61	12.38	22.71	28.54	35.74	51.29
R_{P9}	29 Apr	97	2.20	3.43	4.03	5.41	13.27	8.97	22.00	29.53	34.69	54.09
R_{P10}	1 May	116	2.31	3.17	3.81	4.73	8.61	13.82	25.16	31.23	37.54	51.52
R_{P11}	3 May	36	2.64	3.07	3.90	4.84	6.00	19.83	24.59	30.51	38.76	45.08
R_{P12}	5 May	8	2.83	2.85	3.47	5.16	6.65	17.89	23.06	34.29	41.75	42.05

Appendix Table **D8**. Travel times and migration rates between Lower Monumental Dam and **McNary** Dam (I 99 km) for primary releases hatchery steelhead.

Release	Date	Number	Travel time (days)					Migration rate (km/day)				
			Minimum	20%	Median	80%	Maximum	Minimum	20%	Median	80%	Maximum
$\mathbf{R_{P1}}$	22 Apr	102	2.17	3.09	4.03	5.45	16.79	7.09	21.83	29.53	38.51	54.84
$\mathbf{R_{P2}}$	24 Apr	78	2.31	3.21	3.93	5.04	14.00	8.50	23.61	30.28	37.07	51.52
$\mathbf{R_{P3}}$	26 Apr	98	2.52	3.23	3.93	5.55	11.36	10.48	21.44	30.28	36.84	47.22
$\mathbf{R_{P4}}$	28 Apr	81	2.55	3.21	4.53	7.14	10.86	10.96	16.67	26.27	37.07	46.67
$\mathbf{R_{P5}}$	30 Apr	90	2.33	2.97	3.84	4.73	9.51	12.51	25.16	30.99	40.07	51.07
$\mathbf{R_{P6}}$	2 May	79	2.32	3.32	4.00	5.23	11.64	10.22	22.75	29.75	35.84	51.29
$\mathbf{R_{P7}}$	4 May	73	2.27	3.48	4.25	5.98	16.01	7.43	19.90	28.00	34.20	52.42
$\mathbf{R_{P8}}$	6 May	78	2.94	3.55	4.21	6.21	15.32	7.77	19.16	28.27	33.52	40.48
$\mathbf{R_{P9}}$	9 May	75	2.35	3.07	3.79	5.00	11.46	10.38	23.80	31.40	38.76	50.64
$\mathbf{R_{P10}}$	11 May	67	2.11	2.93	3.63	4.86	7.84	15.18	24.49	32.78	40.61	56.40
$\mathbf{R_{P11}}$	12 May	7	2.88	3.03	3.58	4.58	5.34	22.28	25.98	33.24	39.27	41.32

Appendix Table D9. Travel times and migration rates between the Port of Wilma and McNary Dam (274 km) primary releases of hatchery yearling chinook salmon.

			Travel time (days)					Migration rate (km/day)				
Release	Date	Number	Minimum	20%	Median	80%	Maximum	Minimum	20%	Median	80%	Maximum
R_{P1}	9 Apr	270	13.01	25.34	29.01	32.61	48.28	5.68	8.40	9.45	10.81	21.06
R_{P2}	11 Apr	195	14.53	23.75	27.50	30.39	42.71	6.42	9.02	9.96	11.54	18.86
R_{P3}	15 Apr	242	13.81	23.36	27.18	32.34	45.86	5.97	8.47	10.08	11.73	19.84
R_{P4}	18 Apr	121	13.67	19.16	22.20	26.70	41.83	6.55	10.26	12.34	14.30	20.04
R_{P5}	20 Apr	156	12.98	18.35	21.25	26.99	45.03	6.08	10.15	12.89	14.93	21.11
R_{P6}	23 Apr	297	11.95	15.44	18.47	22.75	40.53	6.76	12.04	14.83	17.75	22.93
R_{P7}	25 Apr	281	9.15	14.07	16.48	21.18	39.75	6.89	12.94	16.63	19.47	29.95
R_{P8}	27 Apr	241	6.75	14.06	16.74	20.78	36.76	7.45	13.19	16.37	19.49	40.59
R_{P9}	29 Apr	219	9.96	13.43	17.37	20.75	36.81	7.44	13.20	15.77	20.40	27.51
R_{P10}	1 May	240	7.13	12.79	15.73	18.65	32.17	8.52	14.69	17.42	21.42	38.43
R_{P11}	3 May	85	9.19	12.66	14.74	17.57	33.06	8.29	15.59	18.59	21.64	29.82
R_{P12}	5 May	13	8.91	12.07	13.68	19.66	27.95	9.80	13.94	20.03	22.70	30.75

Appendix Table **D10**. Travel times and migration rates between the Port of Wilma and **McNary** Dam (274 km) primary releases of hatchery steelhead.

Release	Date	Number	Travel time (days)					Migration rate (km/day)				
			Minimum	20%	Median	80%	Maximum	Minimum	20%	Median	80%	Maximum
R_{P1}	22 Apr	178	11.38	15.75	18.38	23.47	40.15	6.82	11.67	14.91	17.40	24.08
R_{P2}	24 Apr	132	9.75	14.53	17.26	21.52	35.91	7.63	12.73	15.87	18.86	28.10
R_{P3}	26 Apr	154	10.46	13.05	16.16	20.47	34.14	8.03	13.39	16.96	21.00	26.20
R_{P4}	28 Apr	167	9.36	12.57	17.00	19.96	39.60	6.92	13.73	16.12	21.80	29.27
R_{P5}	30 Apr	162	7.47	11.26	14.71	17.44	42.40	6.46	15.71	18.63	24.33	36.68
R_{P6}	2 May	152	8.37	10.68	13.98	16.89	31.01	8.84	16.22	19.60	25.66	32.74
R_{P7}	4 May	126	7.37	10.63	12.78	16.03	28.77	9.52	17.09	21.44	25.78	37.18
R_{P8}	6 May	146	6.71	10.08	11.60	15.14	28.24	9.70	18.10	23.62	27.18	40.83
R_{P9}	9 May	117	6.86	8.49	10.29	14.03	28.00	9.79	19.53	26.63	32.27	39.94
R_{P10}	11 May	99	6.57	8.97	11.09	17.75	43.51	6.30	15.44	24.71	30.55	41.70
R_{P11}	12 May	12	7.99	8.65	11.32	15.99	18.43	14.87	17.14	24.20	31.68	34.29